THE MAGAZINE THAT FEEDS MINDS

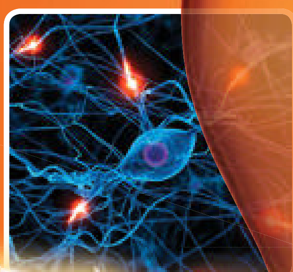
HOW IT WORKS™

SCIENCE · ENVIRONMENT · TECHNOLOGY · TRANSPORT · HISTORY · SPACE

INSIDE

SPACE STATIONS
HOW TO BUILD A 400-TON FLOATING LAB

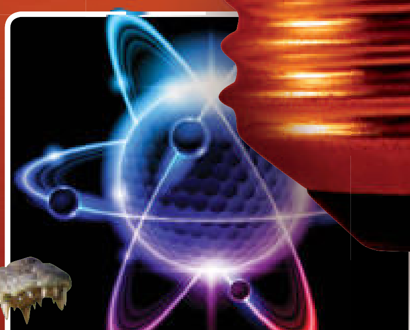
EJECTOR SEATS
How a pilot escapes from an aircraft in an emergency

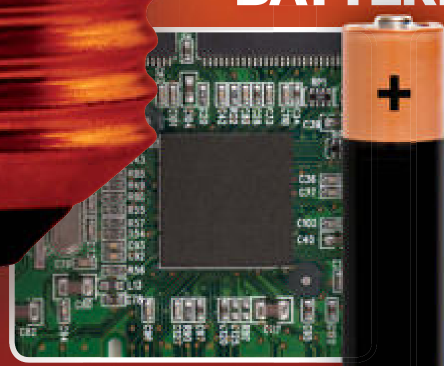


ELECTRICITY

STATIC · GENERATORS
SWITCHES · CURRENT

VOLTAGE · RESISTANCE
BATTERIES · CIRCUITS





THE LONGEST GAS PIPELINE
How 55 billion cubic metres of natural gas is transported 1,200 kilometres along the bottom of the Baltic Sea

WONDERS OF THE NILE
EXPLORE THE WORLD'S MOST FAMOUS RIVER

+ LEARN ABOUT
- HUMAN PELVIS
- OZONE LAYER
- STELLAR JETS
- BINOCULARS
- CALCULATORS
- WRIGHT BROS
- IMPACT CRATERS
- SLOT CANYONS
- HAGFISH
- CABLE CARS
- JOYSTICKS
- COMPOST

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HOW IT WORKS WELCOME

ISSUE 44

The magazine that feeds minds!

Get in touch

Have YOU got a question you want answered by the How It Works team? Get in touch via:

- HowItWorksMagazine
- howitworks@imagine-publishing.co.uk
- www.howitworksdaily.com
- @HowItWorksmag

Page 50
Constructed in low Earth orbit, the International Space Station spans an area the size of an American football field and weighs nearly 420 tons

We explain the ultimate energy this issue: electricity. From what it is and how it works to how it's generated both by machines and in nature. Did you know that right now electric impulses are coursing through your body, helping to send signals to and from your brain enabling you to see, feel and smell the world around you? Pretty amazing.

And what concept could be more mindblowing than that of the engineering tech that enables space agencies to construct massive floating science labs in orbit? Find out how space stations like the ISS, Mir and Tiangong are pieced together bit by bit, hundreds of kilometres above Earth.

We also reveal the remarkable science of the Nile, exploring the natural treasures of the world's longest river. You'll discover its sources, its unique geography and a few of the critters that make their home in and around this wondrous waterway. Enjoy the issue.

Helen Laidlaw
Editor

What's in store…

The huge amount of information in each issue of How It Works is organised into these key sections:

Science Uncover the world's most amazing physics, chemistry and biology

Technology Discover the inner workings of cool gadgets and engineering marvels

Transport Everything from the fastest cars to the most advanced aircraft

Space Learn about all things cosmic in the section that's truly out of this world

Environment Explore the amazing natural wonders to be found on planet Earth

History Step back in time and find out how things used to work in the past

Meet the team…

Robert
Features Editor
If you think the Nile only flows through Egypt, think again. Follow its 4,130-mile course now from page 60.

Helen
Senior Art Editor
The majestic images of Antelope Canyon have inspired me to go check it out for myself.

Ben
Features Editor
Pipes aren't very interesting… unless they're really big: the challenges involved in creating the Nord Stream were insane.

Adam
Senior Sub Editor
We know what the Palace of Westminster looks like from outside, but the inside has centuries of secrets to tell…

CONTENTS

The magazine that feeds minds!

MEET THE EXPERTS

Find out more about the writers in this month's edition of How It Works…

Alexandra Cheung
Electricity

This issue Alex delivers a host of fundamental facts about the world's most 'shocking' form of energy in a special eight-page feature. Learn everything from how we generate electricity to how lightning forms.

Richard Aucock
Classic motorcycle tech

Automotive expert Richard set to work explaining the technology that powers traditional motorbikes such as Harley-Davidsons, revealing the latest engineering evolutions the classic bike has seen.

Jonathan O'Callaghan
Stellar jets

The senior staff writer on our sister title All About Space, Jonathan inspires a sense of wonder in his explanation of stellar jets as he breaks down how this mysterious cosmic phenomenon forms.

Tim Hopkinson-Ball
Palace of Westminster

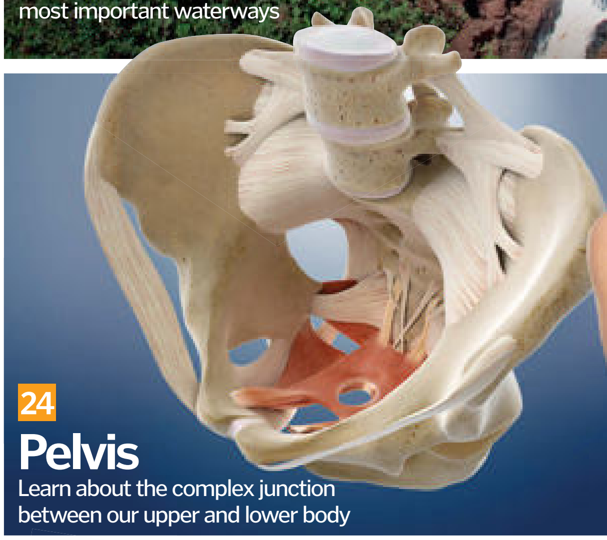
What architectural historian Tim doesn't know about old buildings isn't worth knowing. In History this month he is enlightening us on the construction and design of the British Houses of Parliament.

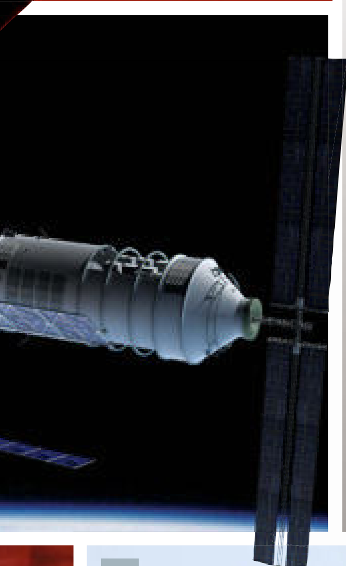
How was the world's longest subsea pipeline constructed?
Find out on page 26

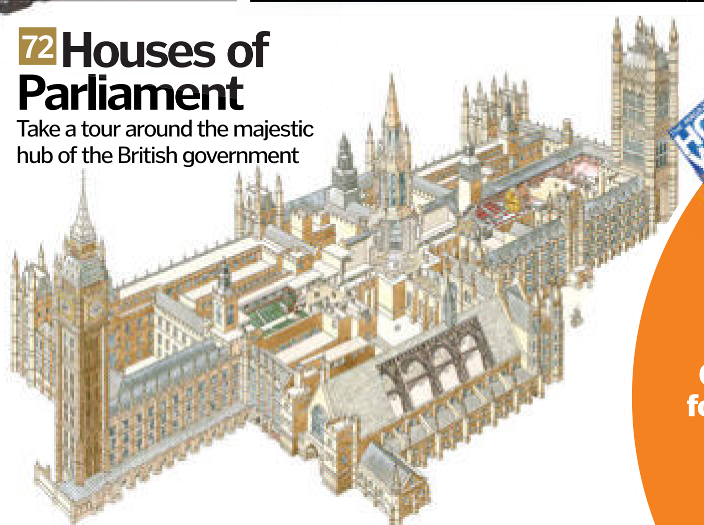
12 COVER FEATURE

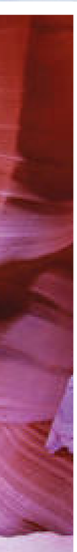
ELECTRICITY

"For lightning, opposite charges accumulate at the base of a cloud and on the ground"









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REGULARS

GLOBAL EYE NEWS

Showcasing the incredible world we live in…

The Sun's many faces revealed

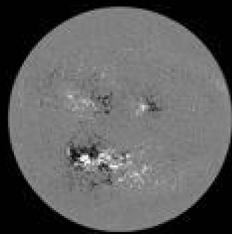
NASA's Solar Dynamics Observatory has released an image of our star that shows it in a whole new light…

By imaging the Sun at different wavelengths, the Solar Dynamics Observatory can closely study its surface and atmospheric activity

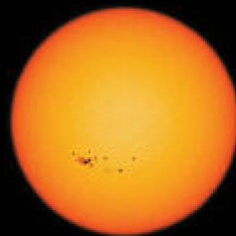
Wavelength guide

Consult our chart to see which ions produce which wavelengths and the specific area of the Sun that each colour represents

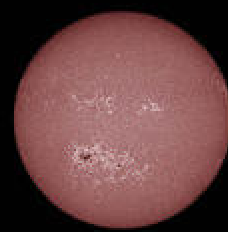
1. Dopplergram
Dopplergrams are maps of velocity on the Sun's surface shot with the Helioseismic and Magnetic Imager (HMI).



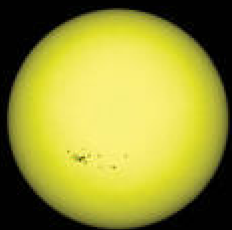
2. Magnetogram
These are maps of the magnetic field on the surface. The white elements are coming towards us and the black are moving away.



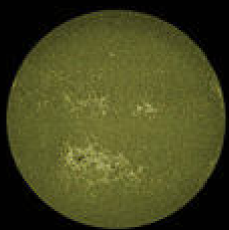
3. HMI continuum
This provides photos of the Sun's surface incorporating a broad range of visible light. It too is captured using the HMI.



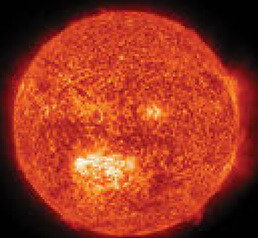
4. Ultraviolet continuum
This shows the surface of the Sun as well as its chromosphere. It is imaged with the Atmospheric Imaging Assembly (AIA).



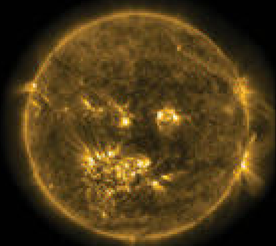
5. White light continuum
This shows the Sun's photosphere in a yellow-green tone.



6. Transition region
Emitted by carbon-4, this reveals an area between the chromosphere and corona and is typically dark yellow.

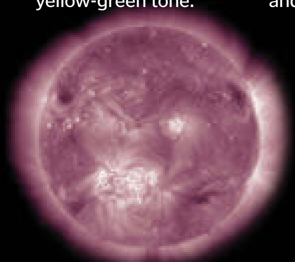


7. Chromosphere
Emitted by helium-2 at around 50,000 Kelvin (K), this light is emitted from the chromosphere layer and appears orange-red.



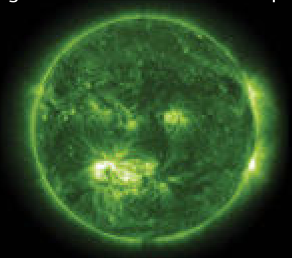
8. Quiet corona
Produced by iron-9 at roughly 600,000K, this wavelength shows the Sun's quiet corona and coronal loops in gold.

9. Solar flares
Light brown indicates iron-12 and iron-24. The former reveals a hot part of the corona and the latter far hotter solar flares.

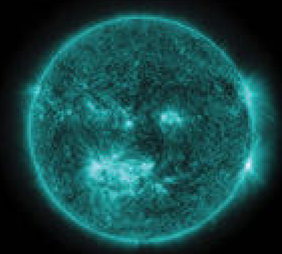


10. Magnetised corona
This wavelength, which is emitted by iron-14, shows hot, magnetically active parts of the corona in a purple shade.

11. More magnetised
Similar to iron-14, this wavelength, produced by iron-16 at 2.5mn K, reveals magnetically active parts of the corona in blue.



12. Hottest flares
Emitted by iron-18 at about 6mn K, this wavelength appears green and clearly distinguishes solar flares from the corona.



13. Flare materials
This teal-toned wavelength reveals the material within solar flares. It is emitted by iron-20 and iron-23 at over 10mn K.

The Solar Dynamics Observatory (SDO) is currently our foremost Sun-analysing spacecraft, spending day after day imaging the star for NASA and the wider scientific community. It is a technologically advanced window into the unique nature and behaviour of our Solar System's powerhouse and, over a five-year mission, is studying it in great detail.

Crucially this investigation relies on analysing the Sun from a multitude of wavelengths, as much of the star's activity is shrouded when viewed in white light (the combination of all visible colours). By breaking down the Sun into wavelengths, individual layers, processes or features can be isolated and studied more closely so their mysteries can be revealed. Among other things, this has already enabled us to track how particles and heat move through the Sun's atmosphere.

"The segments range from dopplergrams of the Sun's surface velocity, through to the activity of its magnetised regions"

The bounty of information that is being gathered by the SDO is no better demonstrated than through the mission's recently released wave-segmented image of the star, which breaks it down into many of its core wavelengths (for a more detailed explanation of these see 'Wavelength guide' above). The segments range from dopplergrams of the Sun's surface velocity, through to the activity of its magnetised regions and the material composition of superhot coronal flares – each only visible due to the observatory's advanced on-board imaging technology.

Foremost among these image-capturing tools are the SDO's Atmospheric Imaging Assembly (AIA) and Helioseismic and Magnetic Imager (HMI). The former system allows scientists to observe how solar material moves around the Sun's atmosphere, while the latter helps them to explore the movement and magnetic properties at the star's surface.

GLOBAL EYE NEWS

The W50 nebula was discovered by researchers based at the US VLA

Manatee-shaped nebula found

One of the largest supernova remnants ever viewed wows astronomers with likeness to a giant sea cow

Measuring nearly 700 light years across, the recently discovered W50 nebula is remarkable not only due to its immense size – it covers two degrees of the night sky – but also due to its uncanny resemblance to the manatee, or sea cow.

The new nebula, which is a vast 20,000-year-old supernova remnant, was discovered when the USA's Very Large Array (VLA) astronomical observatory's main telescope was upgraded recently, with researchers testing the scope and inadvertently stumbling upon the uncharted region of space.

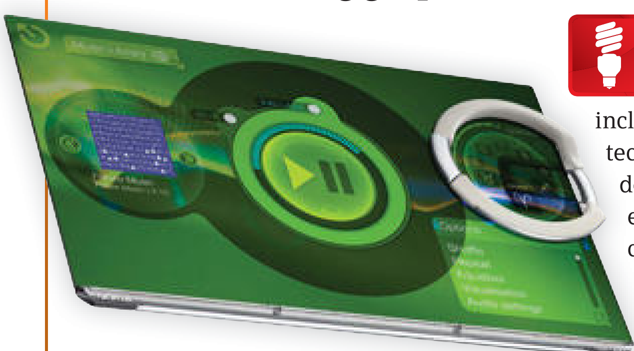
According to the VLA, the W50 nebula cloud formed when a giant star 18,000 light years from Earth in the Aquila constellation exploded as a supernova, spewing a multitude of gases outwards in a large, expanding bubble.

British Science Festival 2013

This September the British Science Festival will be in Newcastle. With hundreds of talks, workshops and exhibitions taking place all over the city, there are chances for the whole family to explore everything from astronomy to zoology. Those attending will hear about exciting developments in the scientific world, with events exploring medical advances, the latest discoveries in space and more. Also joining the Festival will be some famous faces and renowned experts to deliver talks on current scientific theories, as well as their own research. A mini-programme, outlining some of the major events, will be released in June. For more information you can visit **www.britishsciencefestival.org**.

Super-material gets £855m boost

Groundbreaking graphene to make commercial headway thanks to a huge investment



The Nokia Morph concept device uses graphene for both its flexibility and transparency

The European Union has awarded £855 million ($1.35 billion) to a consortium of academic institutions, including Cambridge University, and technology companies such as Nokia, to develop graphene and incorporate it into everyday devices. Currently many concept products are in development, such as the Nokia Morph, but their introduction has been stalled.

The investment, which is to be injected over a ten-year period, has been instigated due to the many potential applications for graphene, including flexible electronics like bendable screen mobile phones, super-powerful batteries for tablets and next-gen computer processors.

Graphene, an atomic-scale honeycomb lattice of carbon atoms, has been identified as such a promising material because of a number of properties. These include lightness – a one-square-metre (3.2-square-foot) sheet weighs only 0.77 milligrams (0.00003 ounces); high conductivity; high optical transparency; large mechanical strength (it is tough and not brittle); as well as chemical insensitivity.

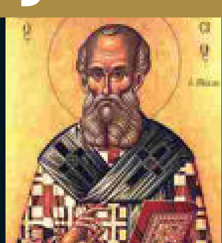
This day in history

21 February: How It Works issue 44 goes on sale, but what

362 CE

Saint returns

Egyptian theologian St Athanasius (right) returns to Alexandria after being exiled.



1613

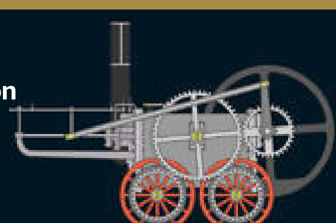
The first Romanov

Mikhail I is elected as tsar of Imperial Russia, beginning the Romanov line.

1804

Do the locomotion

The first-ever self-propelled steam locomotive (built by Richard Trevithick) runs at the Penydarren Ironworks in Wales.



1885

Monumental day

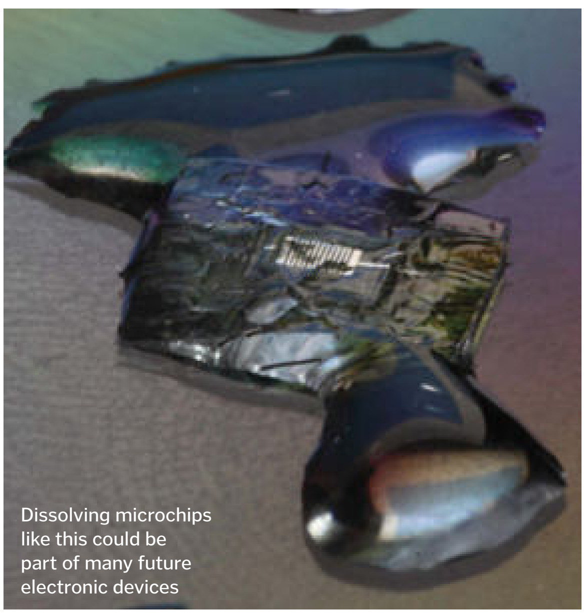
Completed the year before, the Washington Monument (right) is dedicated to the first American president, George Washington.

‘Vanishing’ weapons come to light

Components that easily degrade could help keep military secrets

The US Defense Advanced Research Projects Agency (DARPA) is working on a project that aims to create electronics that simply dissolve into the environment. Currently, when the military uses certain weapons and equipment in operations, the devices are often left behind or are spread around, leaving sensitive components behind for the enemy to recover, repurpose for its own needs or to study.

The Vanishing Programmable Resources programme (VAPR) aims to solve this problem by creating electronics that degrade partly when a certain trigger is activated, like a temperature threshold or a direct command from HQ. It has great potential in commercial electronics too, where discarded electronics can simply decompose harmlessly into their environment.



Dissolving microchips like this could be part of many future electronic devices

Dr Turin and colleagues first conducted the experiment on fruit flies in 2011 and came up with the same results

Wake up and smell the atoms

A new report has lent weight to a controversial theory that says scents involve quantum physics

According to a theory posited by Dr Luca Turin of the Fleming Biomedical Sciences Research Center in Athens, Greece, the cause of specific smells relies on quantum molecular vibrations. The notion, which was first suggested in 1996, contrasts with the currently accepted view that states it is only the shape of molecules that determines scents.

Dr Turin’s theory, however, has just been given a boost, as a recent report in the scientific journal *PLOS ONE* has revealed that humans can distinguish between molecules of the same shape but with different vibrations. The tests – which were conducted double-blind (ie neither the experimenter nor the participants knew which sample was which) – involved preparing two molecule samples of identical shape but with differing levels of vibration; the latter was achieved by replacing the molecule’s hydrogen atoms with heavier deuterium. The participants were then asked to identify which was ‘smellier’.

Despite the results, many remain sceptical of the quantum smell theory, with Nobel prize-winning scientist Richard Axel noting: “Until somebody sits down and seriously addresses the mechanism and not inferences from the mechanism… it doesn’t seem a useful endeavour to use behavioural responses as an argument. Don’t get me wrong, I’m not writing off this theory, but I need data and it hasn’t been presented.”

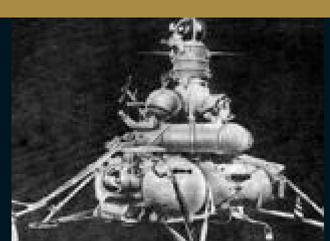
else happened on this day in history?

1916
Longest WWI battle starts
The Battle of Verdun in France begins during World War I.

1925
New mag in town
The New Yorker publishes its first issue, launched by Harold Ross.

1965
Malcolm X assassinated
Human rights activist Malcolm X (right) is killed in New York City.

1972
Luna lands
The Soviet unmanned spaceship Luna 20 (right) lands on the Moon.



1995
High flyer
Adventurer Steve Fossett becomes the first person to fly solo across the Pacific in a balloon.

10 COOL THINGS WE LEARNED THIS MONTH

AMAZING TOPICAL FACTS...

1

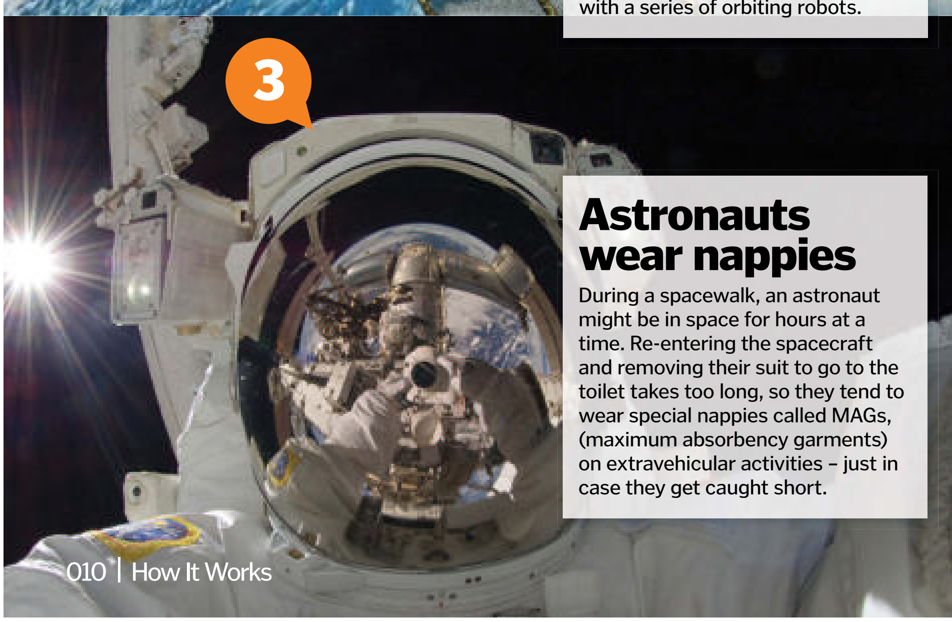
Cats guarded Egyptian tombs

Caracals, also known as desert lynx, were highly prized and respected by the Ancient Egyptians, with many remains excavated today in and around temples. In addition, they have been commonly found depicted in Ancient Egyptian wall art, where they are usually portrayed guarding tombs and other buildings of religious significance.

2

Earth's orbit is due for a tidy

The Defense Advanced Research Projects Agency (DARPA) is planning on harvesting the junk that's floating in geosynchronous orbit (GEO), 35,400 kilometres (22,000 miles) above Earth. In this region there are thousands of broken satellites with useful parts that currently can't be salvaged. DARPA's Phoenix programme plans to catch them with a series of orbiting robots.



3

Astronauts wear nappies

During a spacewalk, an astronaut might be in space for hours at a time. Re-entering the spacecraft and removing their suit to go to the toilet takes too long, so they tend to wear special nappies called MAGs, (maximum absorbency garments) on extravehicular activities – just in case they get caught short.

4

Ancient Greeks used computers

A mechanism called the Antikythera, found in a Greek wreck that has been dated to around 60 BCE, has had new light shed on it since being X-rayed. The cogs and dials that were revealed by the scan have led archaeologists to conclude the device was used to calculate the motion of the stars and planets, indicating scientific tech was way beyond what we previously thought was possible circa 2,000 years ago.

5

Planes pack a punch

Fallstreak holes, or hole-punch clouds, are rare cloud formations whose origins have only been confirmed recently. They can occur when a plane flies through a cloud of supercooled droplets, facilitating a chain reaction where part of the cloud freezes into ice crystals and falls through, punching out dramatic gaps in the cloud layer.

6

Fish can make antifreeze

This is the Bering wolffish, a freaky-looking ocean predator found all around the Asian continent. Apart from looking like something you wouldn't want to bump into in the dark depths, it also produces a kind of natural antifreeze protein to keep its blood flowing in waters that can plunge below zero in winter.

9

Gamma-ray burst hit medieval Earth

Scientists think the most energetic explosion in the universe, a gamma-ray burst (GRB), hit Earth in the eighth century. Researchers have found high levels of carbon-14 in ancient cedar trees and beryllium-10 in Antarctic ice – both of which are created when intense radiation of this type hits atoms in the upper atmosphere. This would have happened from within our galaxy, but it's unlikely Earth's inhabitants would have noticed anything.

Asteroids could be mined by 2015

A new company called Deep Space Industries (DSI) has launched and plans to build an entire fleet of asteroid-mining spacecraft by 2015. They will exploit the abundant resources contained in the thousands of near-Earth asteroids that regularly pass our planet. The water available on these rocks is worth more than gold because of the cost of taking it into space and its value as rocket fuel.

7

Bioluminescence could light up our streets

Bioluminescence – the light that some creatures like plankton, jellyfish and fireflies emit – may one day be used in streetlights. It's already being harnessed in medicine as a biological marker for certain diseases, but research is underway to create bioluminescent products for all kinds of markets, including testing for contaminated water and even glowing drinks.

10

Water bears are tough

8

Tardigrades, or water bears as they're more commonly known, are microscopic creatures. They are able to enter a reversible, death-like state where their metabolism stops, allowing them to survive in extreme conditions that would kill most other life. This includes boiling temperatures, near-absolute zero, deadly radiation, high atmospheric pressure and even the virtual vacuum of space. They can also go without food or water for up to a decade.

ELECTRICITY

Discover what electricity really is and how centuries of science have managed to tame its awesome powers

From lightning bolts to electric circuits, electricity has many faces, but all are linked to the existence and movement of electrical charge. When it comes to powering the gadgets in our homes, the star of the show is the electron – a minuscule but significant particle found in every atom.

An atom consists of negatively charged electrons that orbit a nucleus made up of positively charged protons and electrically neutral neutrons. Opposite charges attract and so electrons are held captive by the nucleus's positive charge. Normally, there are equal numbers of electrons and protons, cancelling out each other's charges and leaving the atom with a neutral charge overall… until electricity comes along to shake things up, that is.

Inside a metal, atoms rub elbows in a tight lattice, sharing one or two of their outermost electrons which meander in all directions. Under the right conditions, these free electrons can be persuaded to travel en masse in one direction. The resulting movement of charge is what we call an electric current.

Electric currents can also be carried by ions – charged particles which occur, for example, when an atom loses or gains an electron. For instance, when salt (sodium chloride) dissolves in water, positively charged sodium ions and negatively charged chlorine ions are freed from the shackles of solid salt and roam freely.

Materials that contain high densities of wandering electrons or ions are called conductors. Metallic conductors like copper are ubiquitous in electrical appliances, but ionic conductors get their share of the limelight inside batteries and even living creatures. Other materials, such as rubber or glass, are configured in such a way that their electrons cling tightly to atoms, making it difficult for a flow of electrons to occur; these are insulators.

All electric currents are not created equal, with several different factors affecting the flow of electrons. When a battery is connected to a light bulb, the current that flows depends on the voltage or potential difference applied by the battery and the resistance of the light bulb.

Imagine a pump forcing water through a pipe: the battery is the pump and the voltage is the 'pressure difference' across the pipe. Increase the voltage and the current increases too. The bulb's resistance, expressed in ohms, is a measure of how difficult it is for the current to pass. Akin to forcing water through a partly blocked pipe, the greater the resistance, the smaller the end current: ie current (amps) is the voltage (volts) divided by the resistance (ohms). ▶

5 TOP FACTS
ELECTRIC TRIVIA

High voltage
1 Static electricity commonly causes your body to build up voltages of 10,000-plus volts. Fortunately the current discharged is too weak to do any serious damage.

Triboluminescence
2 Crunching sugary sweets can separate positive and negative charges as sugar crystals crack. When they recombine the surrounding air is excited, producing a flash of blue light.

Concentrated power
3 A nuclear fission reactor can generate the same amount of electric energy from a kilogram (2.2 pounds) of natural uranium as a power station extracts from 14 tons of coal.

Electric UFOs
4 Static electrical charges on high-voltage transmission lines can cause glowing corona discharges, which may account for UFO sightings in the vicinity of power plants.

Very pr-icy
5 Our fridge-freezers are typically the most energy-greedy of all the household appliances, guzzling approximately £60 ($100) of electricity a year.

DID YOU KNOW? *Early undersea communication cables were often savaged by sharks who mistook their electric fields for prey*

What is electricity?

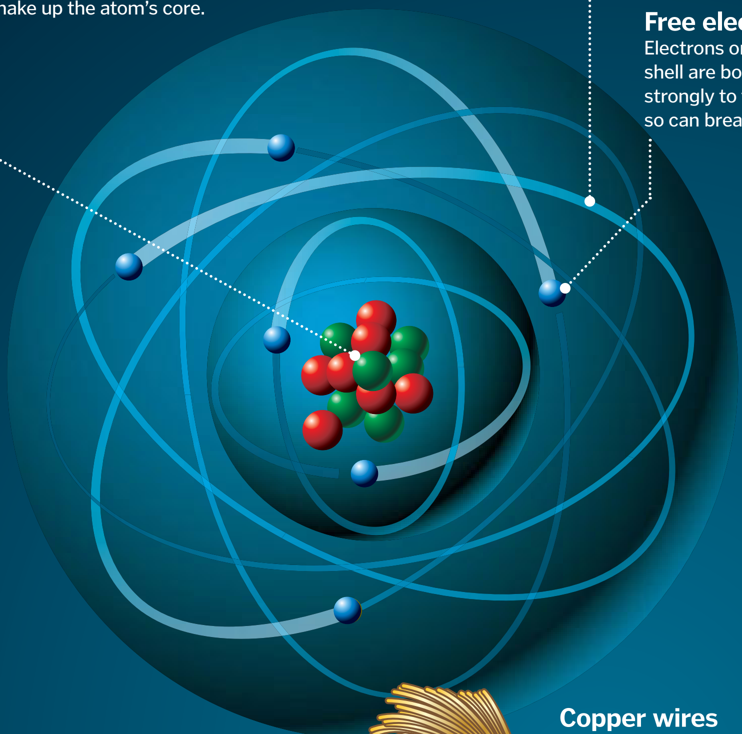
The nature of electricity, where it comes from, how it moves and why it is so powerful

Charge

Nucleus
Positively charged protons and neutrons (with no electrical charge) make up the atom's core.

Shell
One or more negatively charged electrons balance the nucleus's positive charge, orbiting around the nucleus in layers called shells.

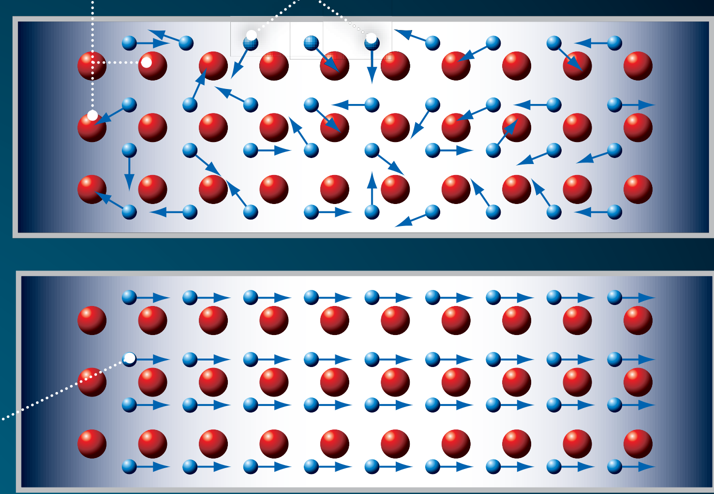
Free electron
Electrons on the outer shell are bound less strongly to the nucleus so can break free.



Current

Metal atoms
Inside a metal, tightly packed atoms form a stable lattice but share their outer electrons.

Free electrons
Thermal energy causes these free electrons to drift randomly in all directions.



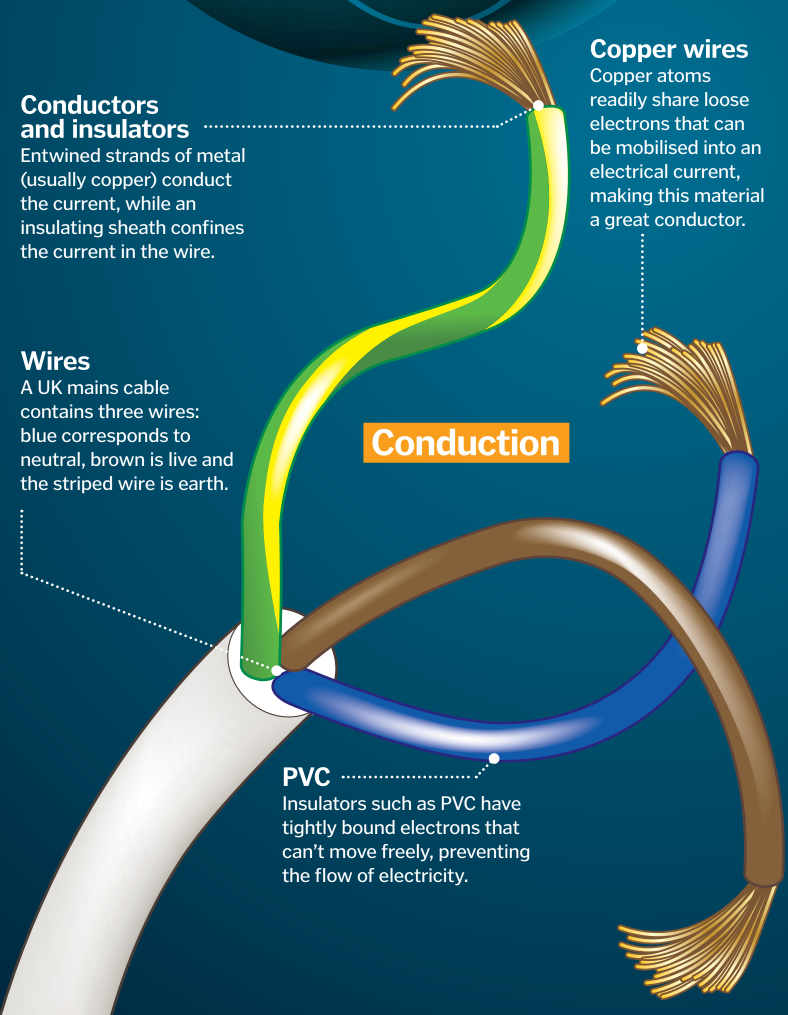
Organised movement
When a voltage is applied, the free electrons all rush in the same direction, creating a current.

Conduction

Conductors and insulators
Entwined strands of metal (usually copper) conduct the current, while an insulating sheath confines the current in the wire.

Copper wires
Copper atoms readily share loose electrons that can be mobilised into an electrical current, making this material a great conductor.

Wires
A UK mains cable contains three wires: blue corresponds to neutral, brown is live and the striped wire is earth.

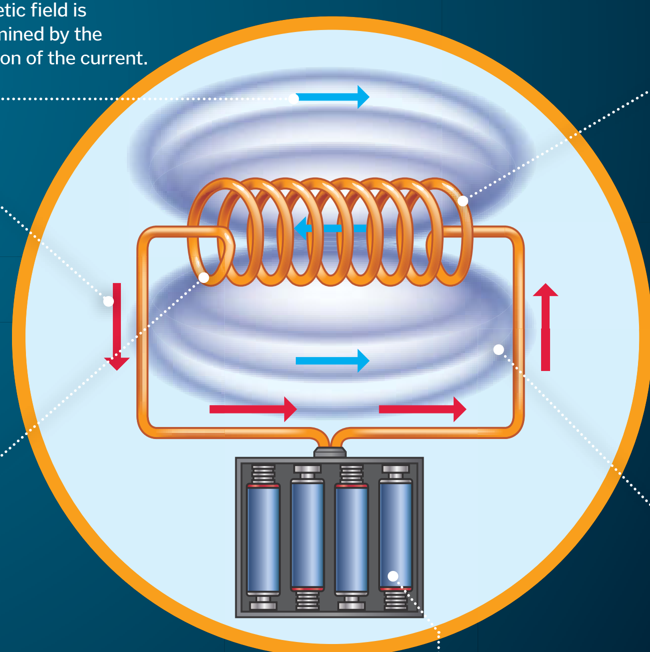


PVC
Insulators such as PVC have tightly bound electrons that can't move freely, preventing the flow of electricity.

Electromagnetism

Direction
The direction of the magnetic field is determined by the direction of the current.

Coil
By wrapping a conductive wire into a tight coil (often around a metal core), the magnetic field is concentrated.



Strength
The electromagnet's strength depends on the intensity of the current and the number of coils.

Power source
A basic electromagnet consists of a conductive coil of wire connected to an energy source (a battery pack, for example).

Induction
Any electric current travelling through a conductor produces a weak magnetic field.

"Right now, tiny electric impulses are racing through you, relaying messages to and from your brain"

Electricity in nature

Electricity has been a fundamental part of human civilisation for over a hundred years, but nature got there well before us.

A fork of lightning tearing across the sky is one of the most vivid depictions of an electrical current, but lightning also exemplifies one of electricity's other faces: static. While electric current is all about moving charges, static electricity is the buildup of charge in one place. In the case of lightning, opposite charges accumulate at the base of a storm cloud and on the ground, generating an increasingly powerful potential difference which is eventually discharged in a blaze of light.

We often witness slightly less spectacular forms of static in the form of little electric shocks. When different materials come into contact, they frequently steal electrons from each other, with some holding on to this charge better than others. The simple act of walking across carpet or taking off a jumper can thus cause your body to accumulate a negative charge. When you touch a conductive object like a door handle, the excess electrons can escape through your fingertips, startling you with an electric shock in the process. Moisture in the air helps to dispel static charges, making these shocks far more common in dry weather.

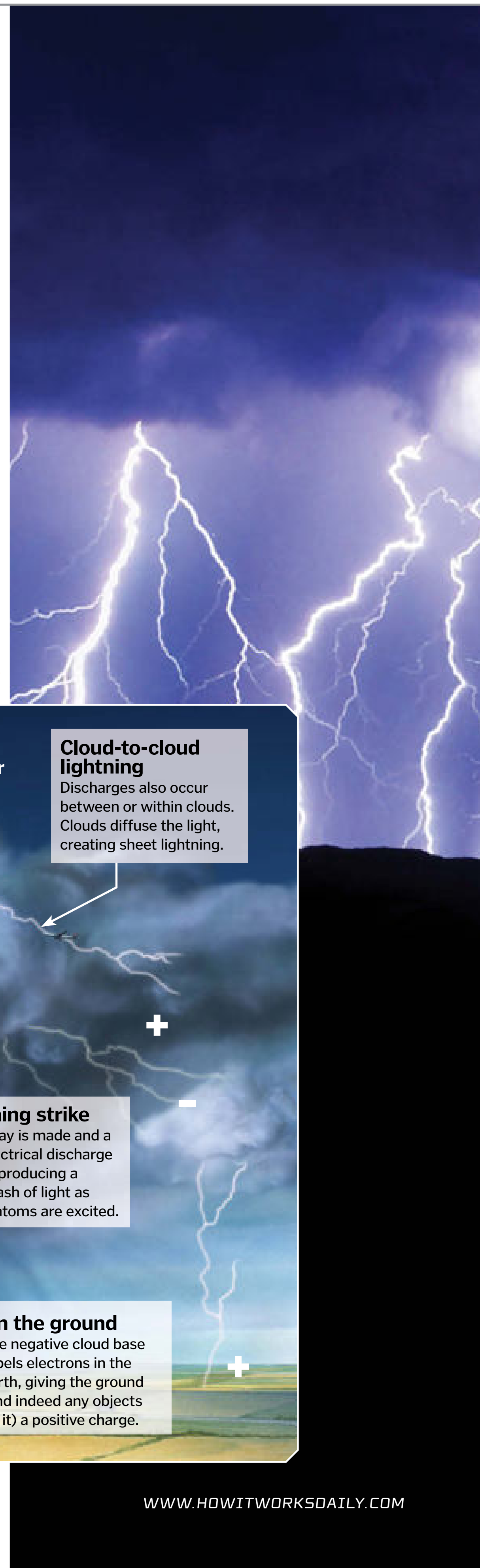
Static may be a minor inconvenience, but your body – like those of all living creatures – can't function without electricity. Right now, tiny electric impulses are racing through you, relaying messages to and from your brain through a dense network of neurons. These cells create an electric potential by controlling the flow of charged ions across their membranes. When stimulated, they reverse this potential, passing on a signal.

Through these electrical impulses, your nerves alert your brain to pain but also convey the multitude of sensations captured by sight, sound, taste, touch and smell. Analysing this input, your brain then uses the same means of communication to tell your muscles to contract, controlling conscious movement but also the subconscious working of organs such as the heart. Unlike the slow-paced chemical communication of, say, hormones, electric impulses allow these important messages to be transmitted almost instantaneously.

The voltages generated by your body are no greater than 0.1 volts, but some animals have evolved far more sophisticated systems to produce electricity. Electric eels, for instance, deliver powerful jolts to stun prey or deter predators. One of numerous electric fish species, they achieve this thanks to as many as 6,000 electrocytes – disc-shaped cells which generate an electric potential. Each of these cells creates a tiny internal negative charge by pumping out positively charged ions.

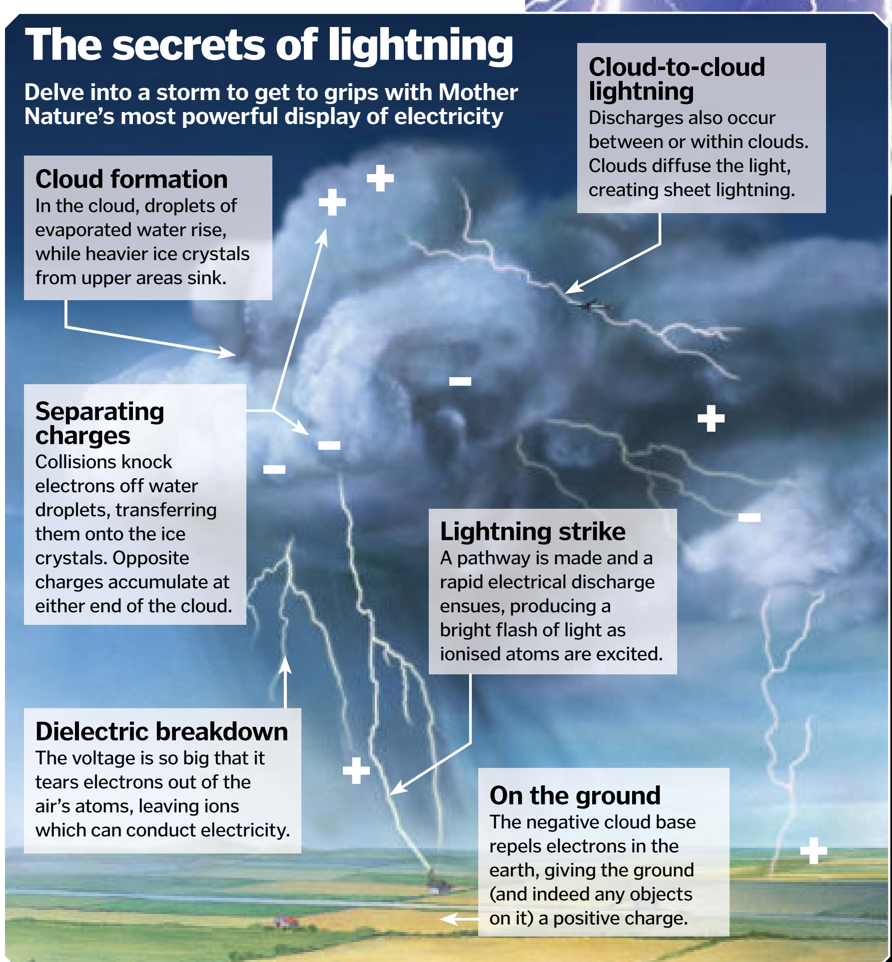
Under the brain's instructions, an electrocyte opens channels which allow positive ions back in, but only on one side of the cell, creating a temporary electric potential across the cell. By stacking up all these tiny batteries and firing them in unison, the electric eel can create an imposing 650-volt shock – more than enough to put a would-be assailant off its lunch.

Other aquatic animals such as sharks have taken a different approach, tuning in to the faint electrical signals emitted by their prey in the water. Since all animals' brains and bodies use electricity, it's an effective way to track down just about any creature in murky waters.



The secrets of lightning

Delve into a storm to get to grips with Mother Nature's most powerful display of electricity



Cloud formation
In the cloud, droplets of evaporated water rise, while heavier ice crystals from upper areas sink.

Separating charges
Collisions knock electrons off water droplets, transferring them onto the ice crystals. Opposite charges accumulate at either end of the cloud.

Dielectric breakdown
The voltage is so big that it tears electrons out of the air's atoms, leaving ions which can conduct electricity.

Cloud-to-cloud lightning
Discharges also occur between or within clouds. Clouds diffuse the light, creating sheet lightning.

Lightning strike
A pathway is made and a rapid electrical discharge ensues, producing a bright flash of light as ionised atoms are excited.

On the ground
The negative cloud base repels electrons in the earth, giving the ground (and indeed any objects on it) a positive charge.

RECORD BREAKERS
UNLUCKY SEVEN

7 strikes

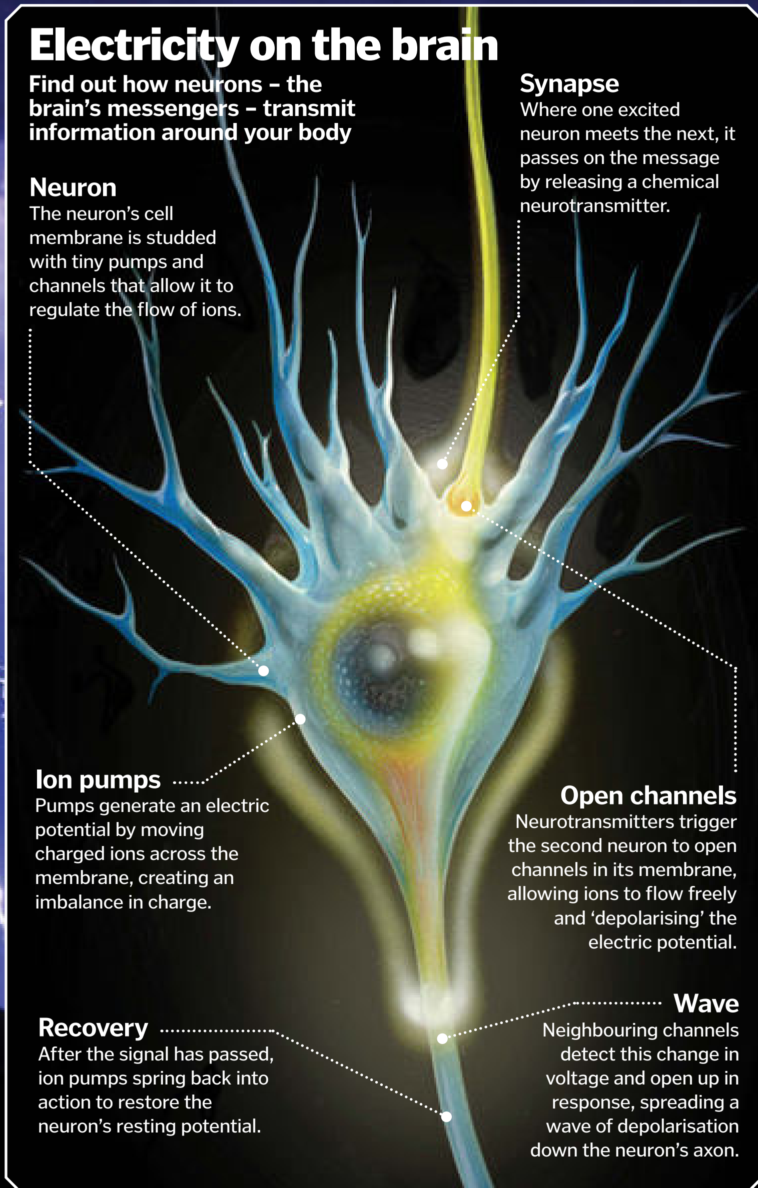
THE HUMAN LIGHTNING ROD

The chances of getting hit by lightning are incredibly small (about 1:10,000 over a lifetime), but odds-defying US park ranger Roy Sullivan survived seven separate strikes over just 35 years.

DID YOU KNOW? *Lightning bolts produce the highest naturally occurring temperatures on Earth, roughly 30,000°C (54,000°F)*

Electricity on the brain

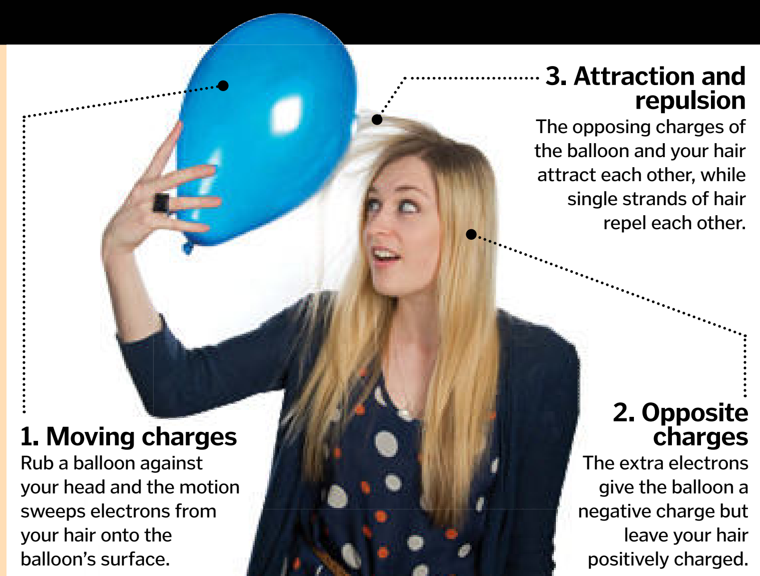
Find out how neurons – the brain's messengers – transmit information around your body



Uses of static

Static electricity is well known for its party tricks, but it has numerous practical uses as well. Laser printers and photocopiers project an image onto a positively charged plate, allowing charge to leak away from lighter parts of the image. Negatively charged black toner then sticks to the dark areas of the image before being transferred onto paper.

Similarly cars are often spray-painted with a positively charged gun, while the vehicle itself is negatively charged, attracting an even layer of paint. Static electricity can even be used to save lives – defibrillators utilise the electrical discharge between two charged paddles to kick-start flagging hearts.



Electrifying animals

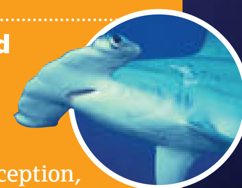
Electric eel

Perhaps the most famous of electric critters, the electric eel is not actually an eel but a freshwater fish native to South America. The fish gets its spark from electricity-generating cells which make up a whopping 80 per cent of its body volume.

Electric ray

The electric ray family is the largest animal group with the power to generate electric shocks, comprising 69 different species. Rays can deliver currents of up to 30 amperes and voltages of 50-200 volts.

Hammerhead shark



Sharks have mastered the art of electroreception, detecting the weak electrical currents generated by their prey's muscular contractions. Voltages down to just one-billionth of a volt are picked up by special pores dotted across their faces. The hammerhead's odd noggin packs in more of these pores than any other shark.

Duck-billed platypus

Along with the echidna, the platypus is one of the very few mammals to detect dinner using electricity. Hunting underwater, the platypus closes its eyes, nose and ears, relying instead on the 40,000 electroreceptors in its bill to locate victims. By swaying its head from side to side it can very accurately pinpoint prey.

"Just like in a kettle, the water gives off high-pressure steam, which is directed towards a turbine"

Generating electricity

Nature may boast some impressive electrical feats, but humans have dreamt up their own methods to generate electricity on demand. The mains power which is lurking behind the sockets in your home is provided by power plants, which typically transform chemical or mechanical energy into electric energy.

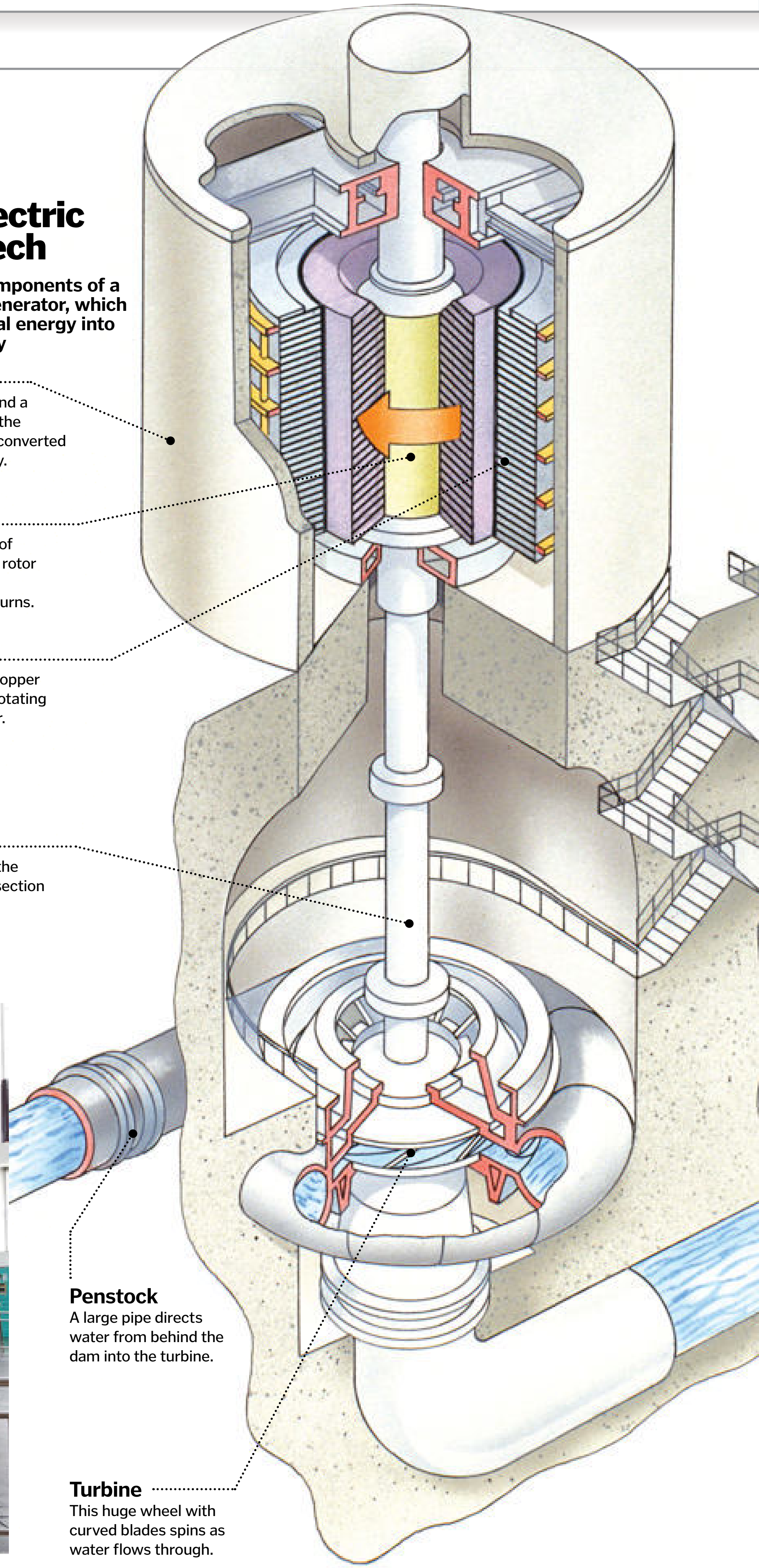
Most large-scale electricity generation relies on a nifty principle called induction. Renowned British electricity pioneer Michael Faraday was the first to discover that a varying magnetic field could 'induce' a potential difference in a conductor. In other words, producing the voltage needed to create an electric current is simply a question of exposing a conductor to a fluctuating magnetic field.

Inside most power plants, the first step in the process is heating water, which is usually achieved by burning fossil fuels such as coal to release their chemical energy. Just like in a kettle, as the water heats up it gives off high-pressure steam, which is directed towards a turbine. Using this turbine to spin a magnet inside a conducting coil of wire (or vice versa) creates the varying magnetic field needed to induce a current in the wire.

Fossil fuels still account for the vast majority of energy produced worldwide, but concerns about global warming and the limited supply of resources like coal make renewable energy sources an increasingly attractive option.

Hydroelectric power tech

Discover the components of a hydroelectric generator, which turns mechanical energy into electrical energy



Generator
Made up of a rotor and a stator, this is where the turbine's rotation is converted into electrical energy.

Rotor
Comprising a series of electromagnets, the rotor generates a strong magnetic field as it turns.

Stator
A stationary coil of copper wire surrounds the rotating part of the generator.

Shaft
The shaft connects the turbine to the rotor section of the generator.

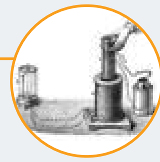
Penstock
A large pipe directs water from behind the dam into the turbine.

Turbine
This huge wheel with curved blades spins as water flows through.

1780s Luigi Galvani uses a small voltage to make a frog's severed legs twitch, uncovering 'animal electricity'.

1800 Alessandro Volta builds the first battery, stacking zinc and copper discs to produce a stable current.

1831 The 'father of electricity' Michael Faraday is the first person to demonstrate electromagnetic induction.



1879 Thomas Edison improves on Joseph Swan's design for the first commercially practical light bulb.

1905 Einstein discovers the photoelectric effect, showing that energy can be harnessed from light.

DID YOU KNOW? *Iceland generates 100 per cent of its electricity from hydroelectric and geothermal power*

How generators work

1 Potential energy
Generators produce electric current by converting other forms of energy into electrical energy. In the case of a hydropower plant (left), a river is blocked off by a dam, trapping a reservoir of water at height. This water stores potential energy which is released when the water flows down from the reservoir.

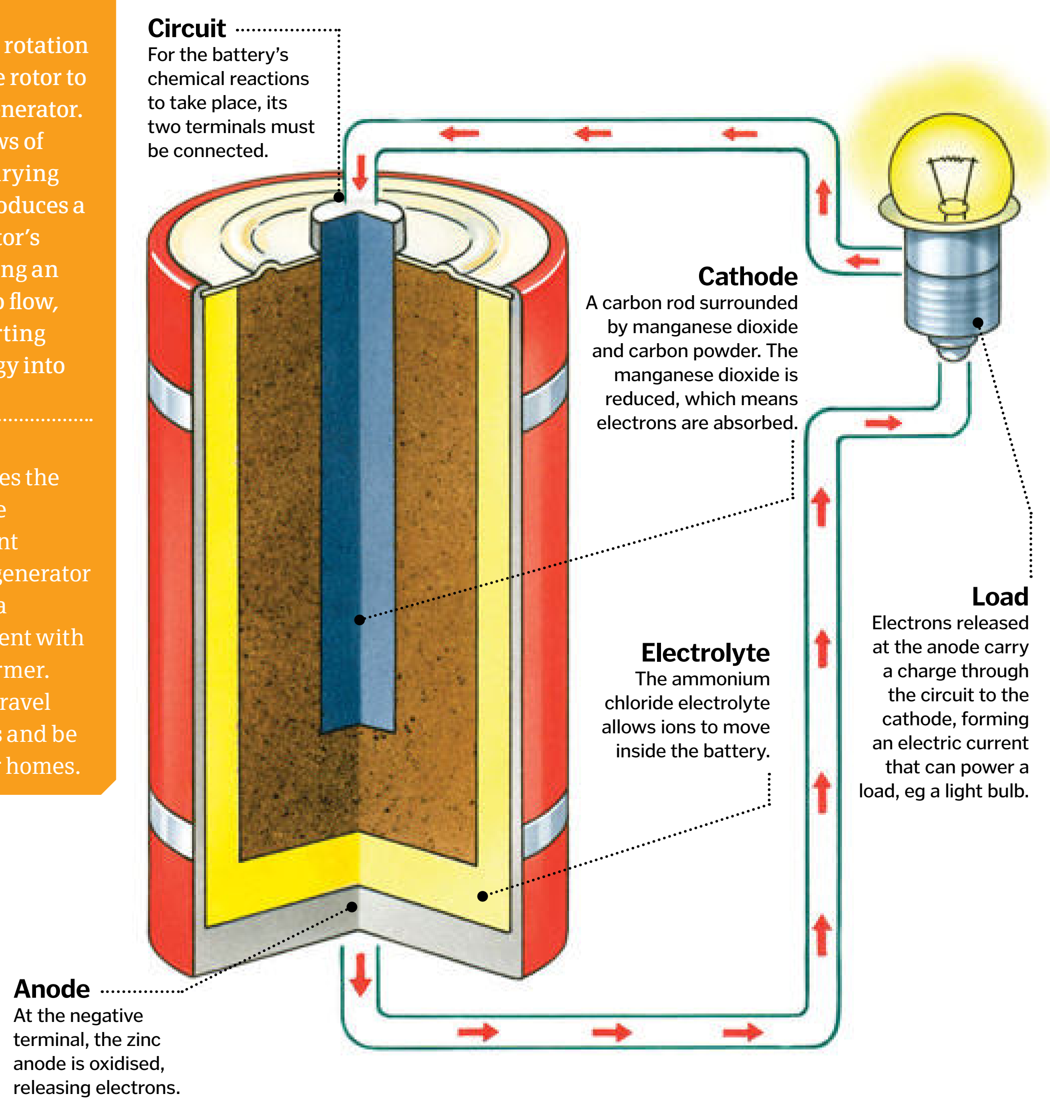
2 Rotating turbine
Water gushes through the penstock, setting the turbine into motion and converting the falling water's energy into mechanical energy. A turbine like the one pictured spins at about 90 revolutions per minute.

3 Induction
The turbine's rotation in turn causes the rotor to spin inside the generator. Exploiting the laws of induction, this varying magnetic field produces a voltage in the stator's coiled wire, causing an electric current to flow, ultimately converting mechanical energy into electrical energy.

4 Final steps
Before it leaves the power station, the alternating current produced by the generator is converted into a high-voltage current with a step-up transformer. It's now ready to travel along power lines and be distributed to our homes.

What's inside a battery?

On a slightly smaller scale, see how a zinc-carbon battery provides power



Some renewable energy technologies use the same blueprint as fossil fuel plants, simply finding different ways to heat water. Nuclear power plants harness the heat unleashed by nuclear fission reactions, while geothermal plants exploit the intense heat at Earth's core.

Other forms of renewable energy follow the same basic principles but take a few shortcuts. Instead of producing heat and steam, they set turbines into motion by capturing mechanical energy directly from flowing water, wind, waves or ocean tides. Although the initial energy source is different, induction is still the underlying principle at work.

Solar power, on the other hand, employs a radically different approach. Solar (or photovoltaic) cells convert sunlight into electricity by taking advantage of the photoelectric effect: the ability of matter to emit electrons when light is shone upon it. Inside a solar cell, photons – the minuscule packets of light energy in sunlight – knock electrons off silicon atoms. These are then organised into an electrical current thanks to silicon's semi-conductive properties, which allow an electrical imbalance to be created and maintained across the solar cells.

Solar power is far more portable than your average power station or wind turbine, making it the ideal power source for everything from pocket calculators to deep-space satellites. The number one choice for portable power, however, is of course the battery.

A battery stores chemical energy which it then converts into electricity when its terminals are connected to a circuit (see above diagram). Chemicals inside the battery react together, releasing electrons from the battery's negative terminal. These electrons then flow through the circuit before being collected by another chemical reaction at the positive terminal. The chemicals fuelling these reactions are gradually depleted, though rechargeable batteries allow the reactions to be reversed, replenishing the battery's charge.

However, one of the most exciting modern technologies for portable power has to be hydrogen fuel cells. Similar to batteries, these use chemical reactions to generate electricity, combining hydrogen and oxygen, with heat and water as the only by-products. Hydrogen fuel cells already power a number of buses and forklift trucks, and the first commercially available hydrogen-powered cars are expected to hit the market in the next few years. Hydrogen's capacity to store energy leads a number of experts to speculate that it will power entire societies in the future.

In the meantime, the vast majority of our daily energy needs are still met by power stations. Generating the electricity is, however, just the beginning of the story – next comes its complex journey to our homes…

> "With its voltage increased, electricity is ready to hit the road on the electrical equivalent of a motorway"

How electricity gets to your home

Electricity distribution is taken care of by a 'grid', a national network of transmission lines connecting power stations to local substations and finally to the homes of consumers. In the US alone, there are over 300,000 kilometres (186,000 miles) of wiring dedicated to electricity distribution. The UK has just one network – the National Grid – while there are three different networks in operation in the States.

The grid cannot store electricity, so the output from power stations must mirror people's varying needs, from the moment you put the kettle on in the morning until you switch off your bedside lamp at night. As a result, at peak periods electricity is often imported from power stations far away, making efficient transmission a must.

Before heading to your home, the electricity generated by a power station has its voltage boosted. When a wire transmits a large electric current, resistance causes it to lose energy as heat. The bigger the current, the more resistance is created and so the greater the waste. The solution is to ramp up the voltage, meaning the same amount of energy can be transported by a much weaker current.

Inside substations, there are clusters of transformers which progressively step up the voltage created by the power station's generator. Once again, induction plays a vital role. A simple transformer consists of a dual electromagnet: a doughnut or horseshoe-shaped iron core with two distinct coils of wire wound around it. The first coil is connected to the generator, creating an electromagnet. The current produced by a power station is alternating (AC), meaning the flow of electrons periodically changes direction (as opposed to a battery which provides a constant flow of electrons in one particular direction – ie direct current, or DC). The electromagnet therefore produces a varying magnetic field, enabling it to induce a voltage in the second coil.

The size of this second voltage is determined by how the wire coils are set up. If the incoming wire has ten loops and the outgoing wire just five, the voltage will be doubled. The opposite arrangement is used to reduce voltages.

With its voltage increased dramatically, electricity is ready to hit the road on the electrical equivalent of a high-speed motorway: high-voltage transmission lines.

High-voltage lines stretch over huge distances, held well out of reach by towering electricity pylons. Before entering towns and cities, substations bring the voltage back down to safer levels. Cables then usually transport electricity underground for extra safety.

Further transformers supply end users with different voltages, with relatively high voltages provided for industrial purposes and lower voltages reserved for domestic use.

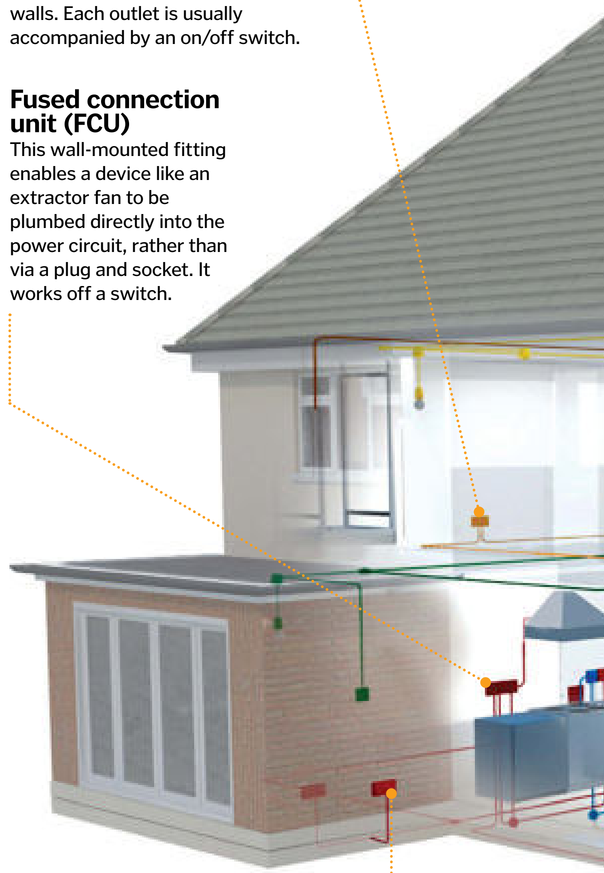
Anyone who's ever taken a hair dryer across the Atlantic will know that countries use different voltages as well as different plug shapes. Largely for historical reasons, most countries worldwide (including the UK and Australia) use 220, 230 or 240 volts, whereas North and Central American countries have almost all opted for 120 volts.

Power house

After its voyage from the power station, how is electricity distributed around a home?

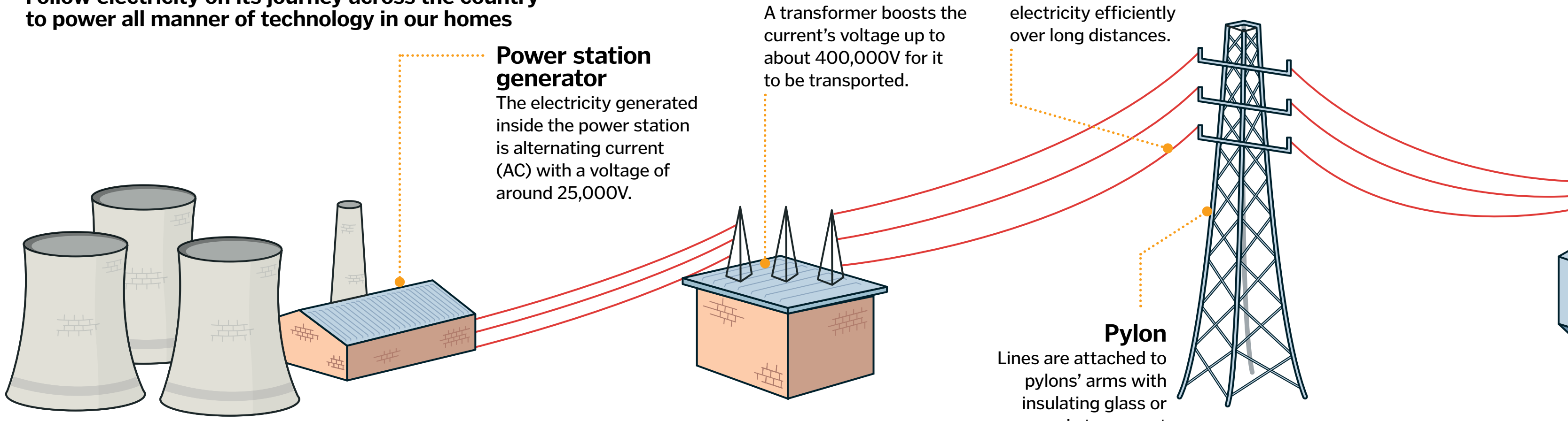
Socket outlet
This familiar square or rectangular fitting can feature one or several outlets for plugging portable items like lamps to power cables in the walls. Each outlet is usually accompanied by an on/off switch.

Fused connection unit (FCU)
This wall-mounted fitting enables a device like an extractor fan to be plumbed directly into the power circuit, rather than via a plug and socket. It works off a switch.



Power station to power socket

Follow electricity on its journey across the country to power all manner of technology in our homes



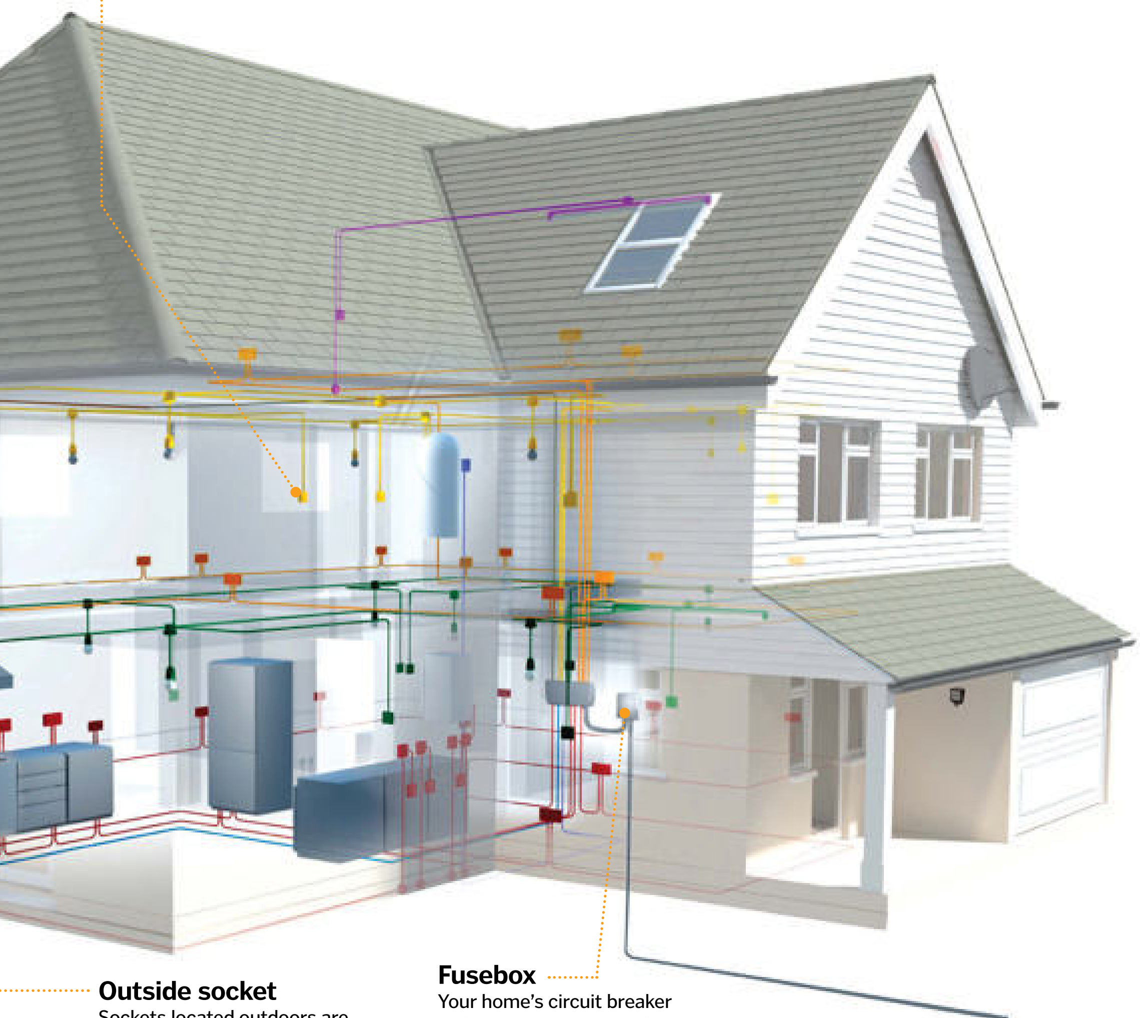
Power station generator
The electricity generated inside the power station is alternating current (AC) with a voltage of around 25,000V.

Step-up transformer
A transformer boosts the current's voltage up to about 400,000V for it to be transported.

Transmission lines
Thick copper or (cheaper) aluminium cables carry electricity efficiently over long distances.

Pylon
Lines are attached to pylons' arms with insulating glass or ceramic to prevent charge seeping out.

DID YOU KNOW? In the UK, electrical accidents at home kill about 70 people every year and injure a further 350,000



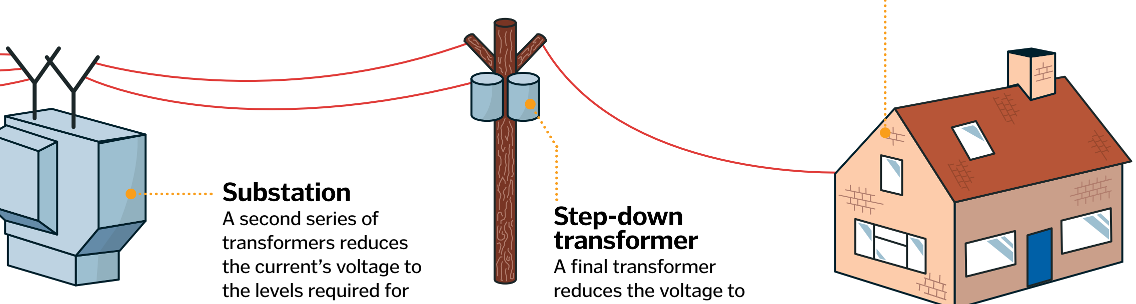
Light switch
Connected to lights in the walls or ceiling, a single plate can have up to four switches (or gangs). Cords might be used in bathrooms to avoid wet hands coming into direct contact with the switch.

House circuitry key:
- Ring main circuit (upstairs)
- Ring main circuit (downstairs)
- Lighting circuit (upstairs)
- Spur to attic
- Lighting circuit (downstairs)
- Immersion heater circuit
- Shower circuit
- Cooker circuit

Outside socket
Sockets located outdoors are generally waterproof and may also feature a high-sensitivity residual-current circuit breaker to prevent electric shocks.

Fusebox
Your home's circuit breaker or fusebox keeps you safe by cutting the electricity supply should there be a malfunction like a power cut.

Meter
An electricity meter keeps tabs on your household's electricity consumption.



Substation
A second series of transformers reduces the current's voltage to the levels required for industrial applications (around 35,000V).

Step-down transformer
A final transformer reduces the voltage to 230V (in the UK) for use around the home.

Electricity in numbers

20.3%
of worldwide electricity is supplied by renewable sources

54kWh
of electricity is the average amount a person in Ethiopia consumes per year

21.3%
of the world's electricity is generated by China

41 electrical appliances in a typical UK home

175kWh
of electricity is used by an energy-saving light bulb in a year

8,991kWh
of electricity is the average amount a person in OECD countries consumes per year

£86
per household is wasted every year by appliances left on standby

54TWh
of electricity is consumed around the world every 24 hours

"The palatine tonsils are thought to be the first line of defence against potential infection"

What are tonsils for?

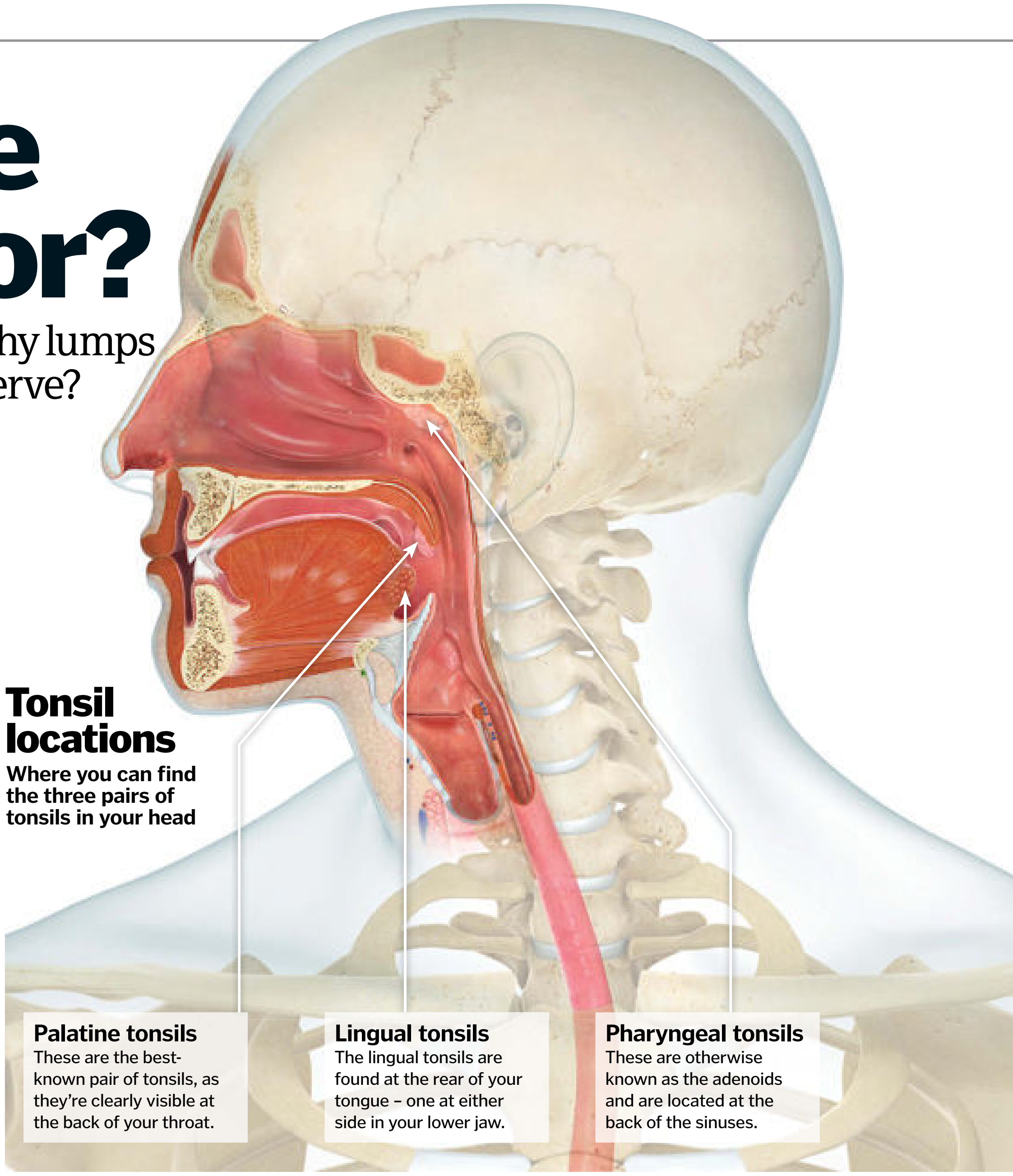
What purpose do these fleshy lumps in the back of our throats serve?

Tonsils are the small masses of flesh found in pairs at the back of the throats of many mammals. In humans the word is actually used to describe three sets of this spongy lymphatic tissue: the lingual tonsils, the pharyngeal tonsils and the more commonly recognised palatine tonsils.

The palatine tonsils are the oval bits that hang down from either side at the back of your throat – you can see them if you open your mouth wide in the mirror. Although the full purpose of the palatine tonsils isn't yet understood, because they produce antibodies and because of their prominent position in the throat, they're thought to be the first line of defence against potential infection in both the respiratory and digestive tracts.

The pharyngeal tonsils are also known as the adenoids. These are found tucked away in the nasal pharynx and serve a similar purpose to the palatine tonsils but shrink in adulthood.

Finally, the lingual tonsils are found at the back of the tongue towards the root where it attaches and, if you poke your tongue right out, you should be able to spot them. These are drained very efficiently by mucous glands and, as a result, they very rarely get infected.



Tonsil locations

Where you can find the three pairs of tonsils in your head

Palatine tonsils
These are the best-known pair of tonsils, as they're clearly visible at the back of your throat.

Lingual tonsils
The lingual tonsils are found at the rear of your tongue – one at either side in your lower jaw.

Pharyngeal tonsils
These are otherwise known as the adenoids and are located at the back of the sinuses.

Lots of bed rest, fluids and pain relief like paracetamol are all recommended for treating tonsillitis

Tonsillitis in focus

Tonsillitis is usually caused by certain bacteria (eg group A beta-haemolytic streptococci) and sometimes viral infections that result in a sore and swollen throat, a fever, white spots at the back of the throat and difficulty swallowing. Usually rest and a course of antibiotics will see it off, but occasionally the infection is very severe and can potentially cause serious problems, or reoccurs very frequently. In these cases a tonsillectomy may be considered – a surgical procedure where the tonsils are removed.

The adenoids are less commonly infected but, when they are, they become inflamed and swell to obstruct breathing through the nose and interfere with drainage from the sinuses, which can lead to further infections. In younger people, constant breathing through the mouth can stress the facial bones and cause deformities as they grow, which is why children will sometimes have their adenoid glands removed.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"The reason for this shift is that, due to the motion of the ambulance, the sound waves bunch up"

What are probiotic bacteria?

Not all bacteria are harmful, with some even bringing benefits to the human body

Contrary to almost a hundred years of bacteria being treated as something that must be eradicated – typically with antibiotics – modern evidence has demonstrated that actually many bacteria are essential to humans and our daily functions.

The combination of these bacteria, which can be found throughout the body, is referred to as the human microbiome – encompassing all manner of microbes and their genetic elements. One notable example of these tiny organisms is Lactobacillus, a genus common in the human gastrointestinal tract known to produce a lactic acid environment that inhibits growth of some harmful bacteria. There are also various strains of Bifidobacterium, which aid the decomposition of carbohydrates and proteins.

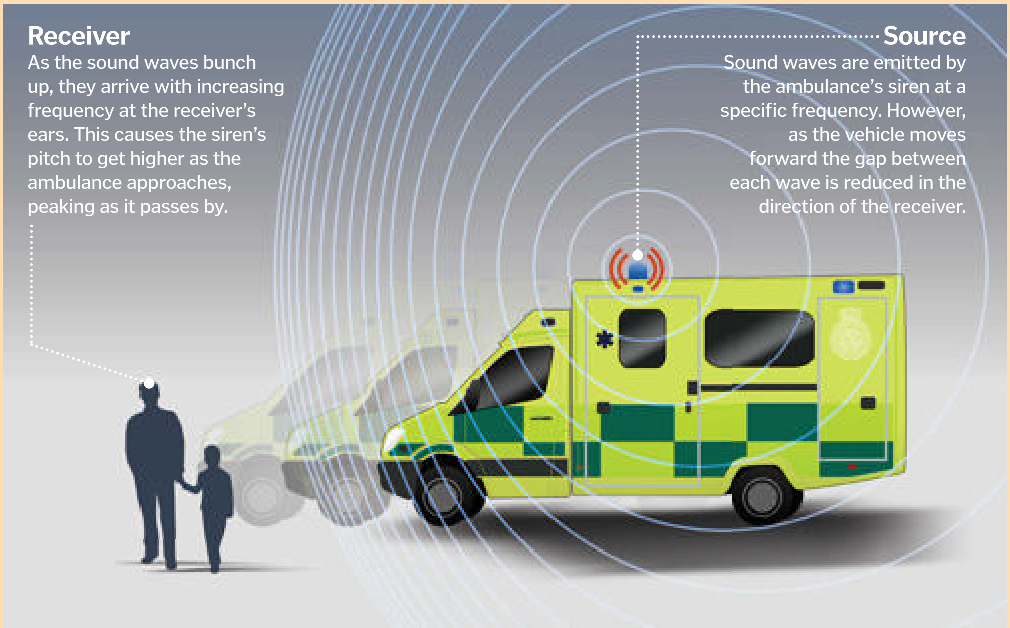
Importantly, while research has confirmed many members of the microbiome do indeed aid bodily functions, additions included in probiotic foods – such as popular sweet yoghurt drinks – are yet to have their advertised benefits ratified by official bodies like the European Food Safety Authority.

This is a colour-enhanced scanning electron micrograph of the probiotic bacterium Bifidobacterium pullorum, which helps with digestion

Understanding the Doppler effect

Discover why the sound of a siren or F1 car changes depending on its proximity

The Doppler effect – named after Austrian physicist Christian Doppler – is the perceived difference between the frequency at which sound, or light, waves emanate from a source and at which they are received. A good everyday example is an ambulance approaching a pedestrian. The vehicle's siren emits sound waves at a certain frequency, which if both the ambulance and person were stationary would remain at a constant pitch. But, as the vehicle speeds towards the person, the pitch gets ever higher until it passes, lowering again as it recedes. The reason for this shift is that, due to the motion of the ambulance, the sound waves bunch up, taking less and less time to reach the pedestrian's ears . This bunching up effect increases the number of waves reaching the receiver at once, leading to an apparent fluctuation in pitch.



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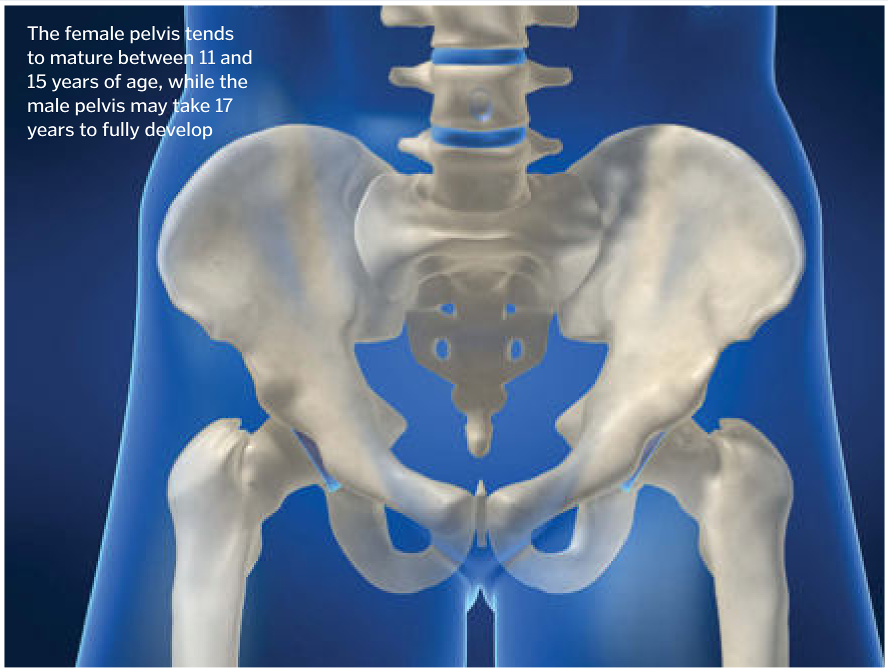
"When it is fully formed, the human pelvic skeleton can comprise more than ten bones"

The human pelvis

Linking our upper and lower body this basin-shaped complex of bones is essential for getting around



The female pelvis tends to mature between 11 and 15 years of age, while the male pelvis may take 17 years to fully develop

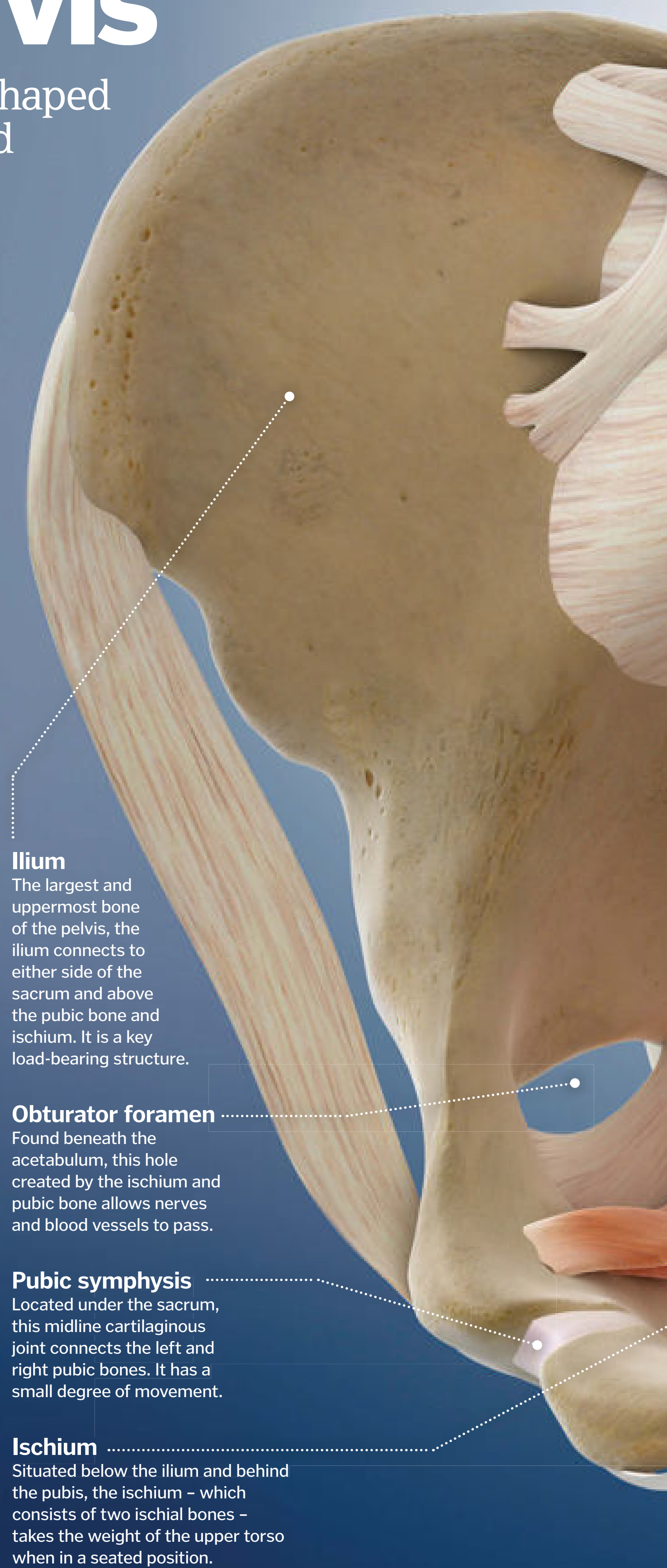
The pelvis is an essential part of the skeleton which acts as a junction between the abdomen and the legs. It consists of eight key structures: the sacrum, ilium, ischium, pubic bone, pubic symphysis, obturator foramen, acetabulum and coccyx, which are laid out symmetrically. Together these make up the bony pelvis.

The role of the pelvis is threefold. Firstly, it serves as a connecting mechanism between the torso and the legs. Secondly, it is a vital support and balance structure for the upper body. And thirdly it provides a protective, containing cradle for the intestines, bladder and internal sex organs.

The pelvis – technically referred to as the pelvic girdle in this context – consists of a pair of hipbones connected to the base of the vertebral column. Each hipbone is formed from the fusing of three smaller bones (the ilium, ischium and pubic bone) that, when combined, link the base of the spine (the sacrum) to the lower limbs via the acetabula – the cup-shaped cavities into which the femurs fit via ball-and-socket joints.

The pelvic girdle, when fully formed, resembles a roughly cylindrical basin, or the pelvic cavity, perforated on the underside with two main sets of holes. These are the aforementioned acetabula, as well as the obturator foramina, the former receiving the thighbones (femurs) and the latter allowing for the passage of nerves and blood vessels between the torso and the lower body.

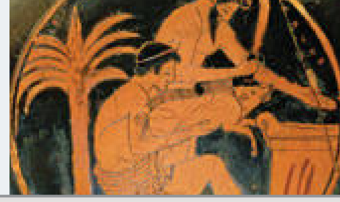
Interestingly, in infants the pelvis is a far narrower structure than at full maturity, offering little – if any – support. This changes as we grow, with the pelvis broadening and tilting under the influence of increased walking and standing. When it is fully formed, the human pelvic skeleton can comprise more than ten bones, with the number determined by the composition of the individual's tailbone (coccyx). This structure is composed of three to five successively smaller caudal vertebrae located at the base of the sacrum.



STRANGE BUT TRUE
BONY SACRIFICE

Which part of the pelvis was once offered to gods?

A Sacrum **B** Coccyx **C** Ilium

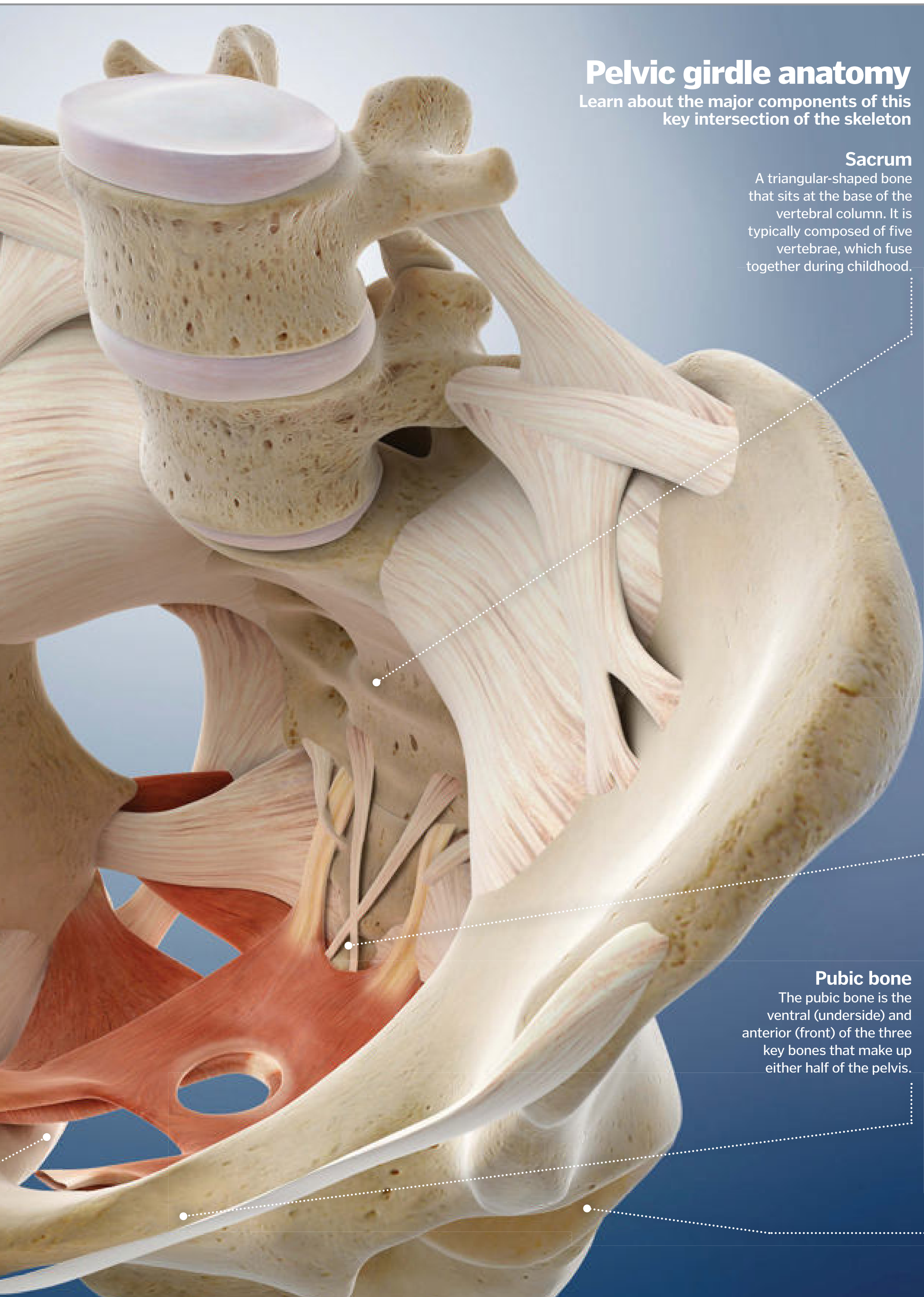


Answer:
The sacrum, derived from the Latin for 'sacred', was sometimes taken from animals and sacrificed to Ancient Greek gods. It was considered to be the seat of the reproductive organs and therefore the creation of life, so had very spiritual associations.

DID YOU KNOW? *Forensic anthropologists can use the pelvis to determine a skeleton's sex and also guess its age at death*

Pelvic girdle anatomy

Learn about the major components of this key intersection of the skeleton



Sacrum
A triangular-shaped bone that sits at the base of the vertebral column. It is typically composed of five vertebrae, which fuse together during childhood.

Coccyx
The tailbone is a curved, semi-flexible structure located at the lower end of the spine. It is made up of three to five successively smaller caudal vertebrae.

Pubic bone
The pubic bone is the ventral (underside) and anterior (front) of the three key bones that make up either half of the pelvis.

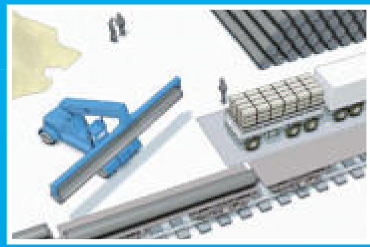
Acetabulum
A concave surface within the lower pelvis, the acetabula are two deep cavities into which the top of the femurs sit on either side of the pelvis.

Male vs female

Differences between the male and female pelvis are numerous and stem, primarily, from the female's reproductive system. For example, the female pelvic basin is broader than the male equivalent, the pubic symphysis short and the pubic bones connect in a wider angle with each other. In addition, the coccyx has a greater degree of movement and the two acetabula are spaced farther apart. All together these allow a rounded and spacious birth canal – which hasn't been an evolutionary priority in the male of the species.

Mega pipes

The Nord Stream gas pipeline is an epic structure that offers a glimpse of the advanced engineering needed to fuel the modern world



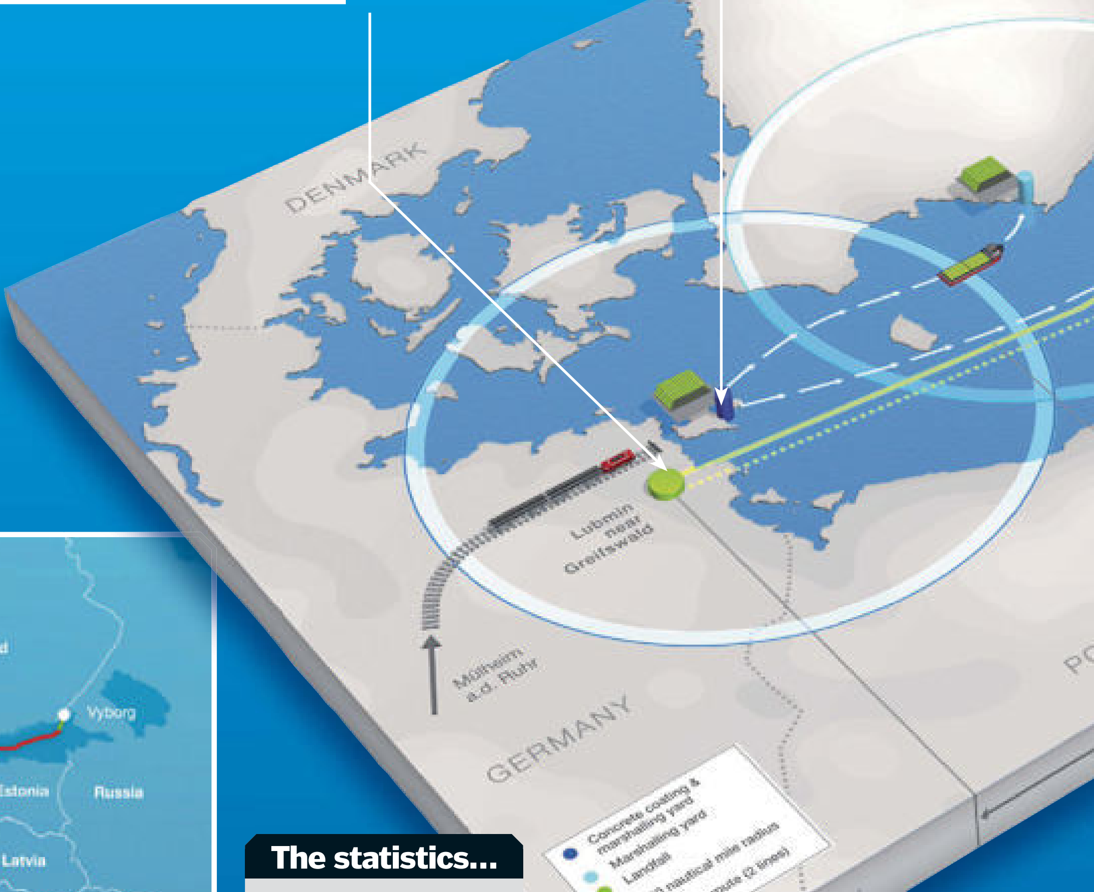
Mukran facility
The Mukran facility receives raw materials for the pipeline by rail including cement, magnetite, sand and aggregate. These are shipped to the Swedish marshalling yards of Karlskrona and Slite for distribution.

Right now the planet's demand for energy is growing at an exponential rate. Each year more people are born and more homes are built to accommodate them, with each new property needing to be supplied with electricity and gas. This hunger for energy is ravenous and, looking forward, it seems to show no sign of abating.

To combat this ever-rising need for power, creative new energy-generating technologies are being implemented, with renewability at their heart. Progress has and is already being made in this pursuit, with wind farms, marine turbines and solar power stations increasingly contributing to national energy grids. This is undoubtedly the best way forward for our planet. Unfortunately though, right now the demand for energy far outweighs that being inputted by renewable sources, with a very real deficit needing to be addressed.

For Europe, that deficit is being met by the brand-new Nord Stream twin pipeline system, a 1,224-kilometre (760-mile) pair of gas pipes ▶

Lubmin plant
The German landfall facility lies in the Bay of Greifswald. This is a filtering station, with gas received via the Nord Stream cleaned and heated to prevent condensation prior to being distributed to people's homes.



The statistics...

Nord Stream

Length: 1,224km (760mi)
Pipe segments: 199,755
Diameter of pipe: 1.2m (3.9ft)
Pipe segment weight: 24 tons
Lifetime: 50+ years
Houses fuelled: 26mn

5 TOP FACTS
NORD STREAM

Pitch perfect
1 The Solitaire pipe-laying vessel used to build the Russian end of the Nord Stream is nearly 400 metres (1,300 feet) long – the equivalent of four football pitches laid end-to-end.

Going with the flow
2 It takes 12 days for the gas to flow through Nord Stream's 1,224-kilometre (760-mile) pipeline running all the way from north-west Russia to north-east Germany.

Mega fleet
3 During Nord Stream's construction a total 148 vessels of various types were used. These were involved in survey, construction and logistics operations.

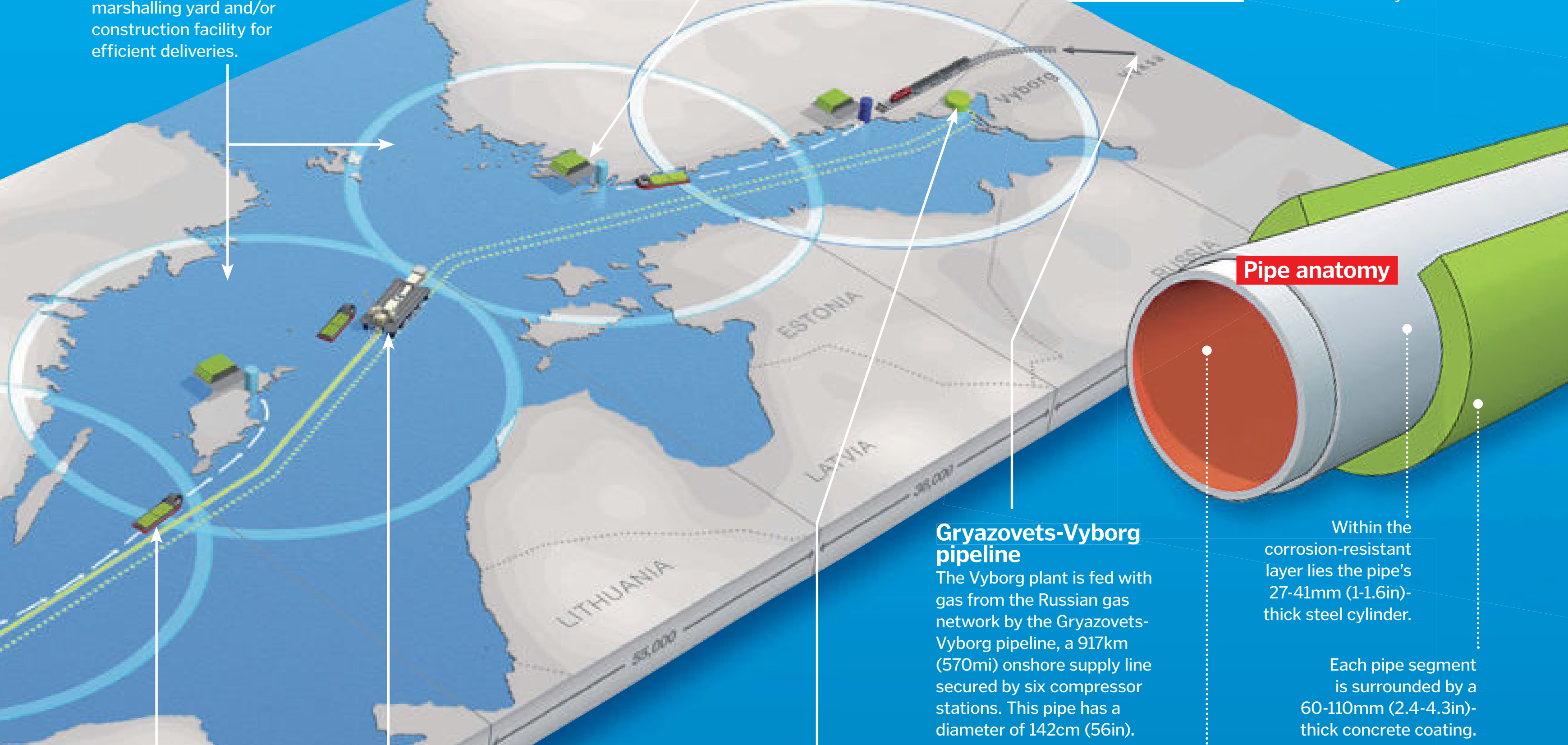
Weight for it
4 The total amount of steel used in the construction of the Nord Stream pipeline came to over 2.42 million tons – that's roughly 242 times the weight of the Eiffel Tower!

Equator
5 Prior to building, over 40,000 kilometres (24,850 miles) of marine terrain was geophysically surveyed – about the circumference of the Earth at the equator.

DID YOU KNOW? *The entire Nord Stream gas pipeline took just six years to build*

A tour of the Nord Stream

HIW looks at the core facilities along the route of the pipeline and how the various stages were assembled



Operational zones
The Nord Stream is split into five overlapping operational zones, each with a dedicated marshalling yard and/or construction facility for efficient deliveries.

Marshalling yard
As well as the Kotka and Mukran facilities there are three other marshalling yards along the route, located at Karlskrona and Slite in Sweden, and Hanko in Finland. Pipes and materials are stored here for distribution by tankers.

Gryazovets-Vyborg pipeline
The Vyborg plant is fed with gas from the Russian gas network by the Gryazovets-Vyborg pipeline, a 917km (570mi) onshore supply line secured by six compressor stations. This pipe has a diameter of 142cm (56in).

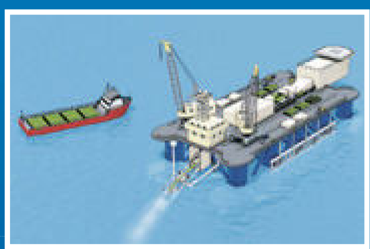
Pipe anatomy
Within the corrosion-resistant layer lies the pipe's 27-41mm (1-1.6in)-thick steel cylinder.

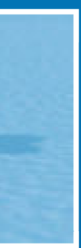
Each pipe segment is surrounded by a 60-110mm (2.4-4.3in)-thick concrete coating.

Finally, on the inner face of the steel cylinder lies a 1mm (0.04in)-thick anti-friction layer.

Vyborg plant
The Russian landfall facility in Portovaya Bay near Vyborg receives gas from the Russian gas network and compresses it to adequate pressure for transportation via the Nord Stream to Germany.

Laybarge
Pipes from the carrier ships are installed by vast laybarges. These colossal vessels measure up to 397m (1,302ft) in length, needing to carry hundreds of pipes at any one time, as well as the range of machinery required to lay them.





Carrier vessel
Concrete pipes from the marshalling yards and Kotka and Mukran facilities are delivered to the Nord Stream's three laybarges on huge carrier vessels. These ships can transport hundreds of pipes on each journey.

The laybarge fleet

Castoro Dieci (165m/541ft)
The Castoro Dieci laid pipes in the German waters around the Lubmin region.

Castoro Sei (193m/633ft)
The Castoro Sei laid pipes in German, Danish, Swedish, Finnish and Russian waters.

Solitaire (397m/1,302ft)
The world's largest pipe-laying ship worked in Finnish and Russian waters.

> "As of January 2013, the pipeline has the capacity to transport up to 55bn m³ of natural gas per year"

running along the bottom of the Baltic Sea. The pipeline links north-west Russia with north-east Germany and, as of January 2013, has the capacity to transport up to 55 billion cubic metres (1.9 trillion cubic feet) of natural gas per year from the gas fields of Siberia directly into the heart of Europe.

As you might expect, the pipeline is not without its critics. With a life span in excess of 50 years, the Nord Stream will see non-renewable energy continued to be spent and, due to the pipeline's large capacity, at an increased rate for the foreseeable future. In addition, due to the pipeline passing through 1,224 kilometres (760 miles) of the Baltic Sea, environmental organisations – including the World Wide Fund for Nature – have raised serious concerns regarding the project's potential to damage or displace complex ecosystems and delicate marine habitats.

While these environmental concerns are something we can't ignore in the long term, there is no denying the fact that the Nord Stream is one of the most impressive engineering feats ever undertaken. On both a macro and micro level, the project is centred around cutting-edge technology such as an undersea station capable of housing 24 divers, advanced logistical systems like pipe-laying barges up to four times the length of a football pitch, and supersmart electronics able to operate machines and vehicles hundreds of metres beneath the sea's surface.

In this feature **How It Works** takes a closer look at the Nord Stream twin pipeline system to find out not only how it was put together, but also – regardless of its non-renewable crutch – how it demonstrates just how science and technology can help improve the lives of millions and power future development.

Diving system
The Skandi Arctic support vessel deploys an underwater station capable of housing 24 divers. The workers eat, sleep and live in the station for the duration of each installation.

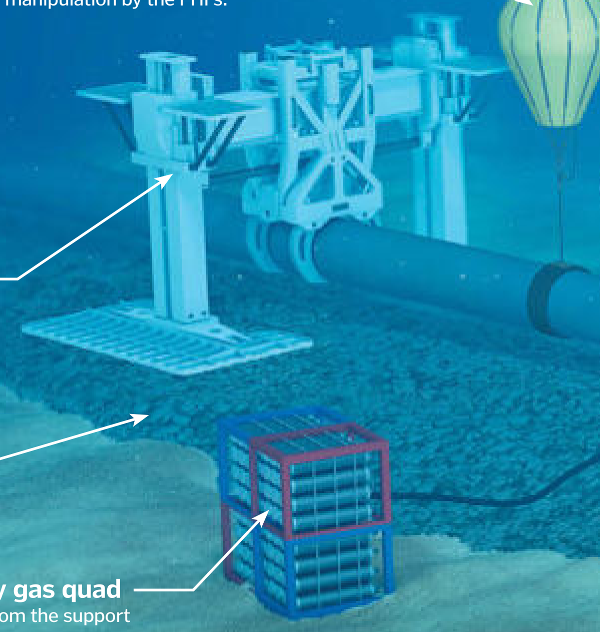
Lift bags
Each pipe segment to be installed is equipped with lift bags filled with air. These bags can support up to 20 tons and help stabilise the pipe for manipulation by the PHFs.

The smartest PIGs on the planet?

The Nord Stream has its integrity checked regularly by pipeline inspection gauges (PIGs). PIGs are like intelligent drain cleaners, being inserted into the pipes before proceeding to automatically detect the smallest changes in the pipeline's structure – due to corrosion, for example – and recording that for later analysis at a control station. PIGs are also able to register any possible movements that the pipeline may have made since installation, such as those generated by small impacts. Each PIG is inserted into the Nord Stream pipeline via a launcher based in Russia, before being fired through the system and extracted in Germany. If any issues are detected, a maintenance and repair team is dispatched to investigate.

Pipe laying in action

Learn about the machines, tools, techniques and processes that go into laying undersea pipe networks



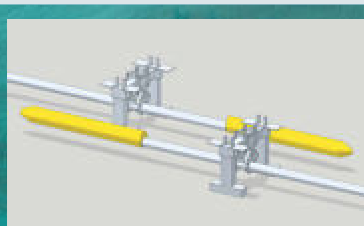
Pipe-handling frame (PHF)
The pipe-handling frames are responsible for positioning the pipes in the correct place for joining together. They can lift up to 150 tons and can move the pipes both vertically and horizontally.

Gravel bed
Prior to any pipe segments being delivered, a gravel layer is deposited onto the seabed. This provides a stable foundation for the welding habitat and pipe-handling frames during the installation.

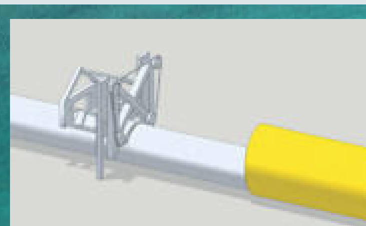
Emergency gas quad
If gas supply from the support vessel fails, an emergency supply can be gathered from the gas quad, providing the welding habitat with breathable air for up to 72 hours.

Tie-in sequence

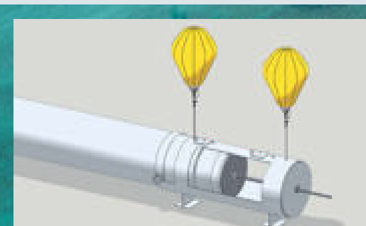
Follow the seven-stage process which was used to join two segments of pipe together



1. Survey
Prior to any human divers arriving at the installation site, a survey is conducted by ROVs to determine everything is in place.



2. Cutting
When in position, the pipe segments may overlap. If so, a diamond wire cutter is used to slice the high-tensile steel.



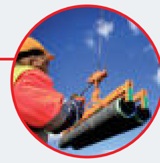
3. Plugs
Welding plugs are inserted into each end of the segments to hold back the water from the welding area of the habitat.

KEY DATES IN THE PIPELINE…

2006 In November the logistics concept is started for the Nord Stream pipeline.

2007 A year later construction work begins on the Mukran site in Lubmin, Germany (right).

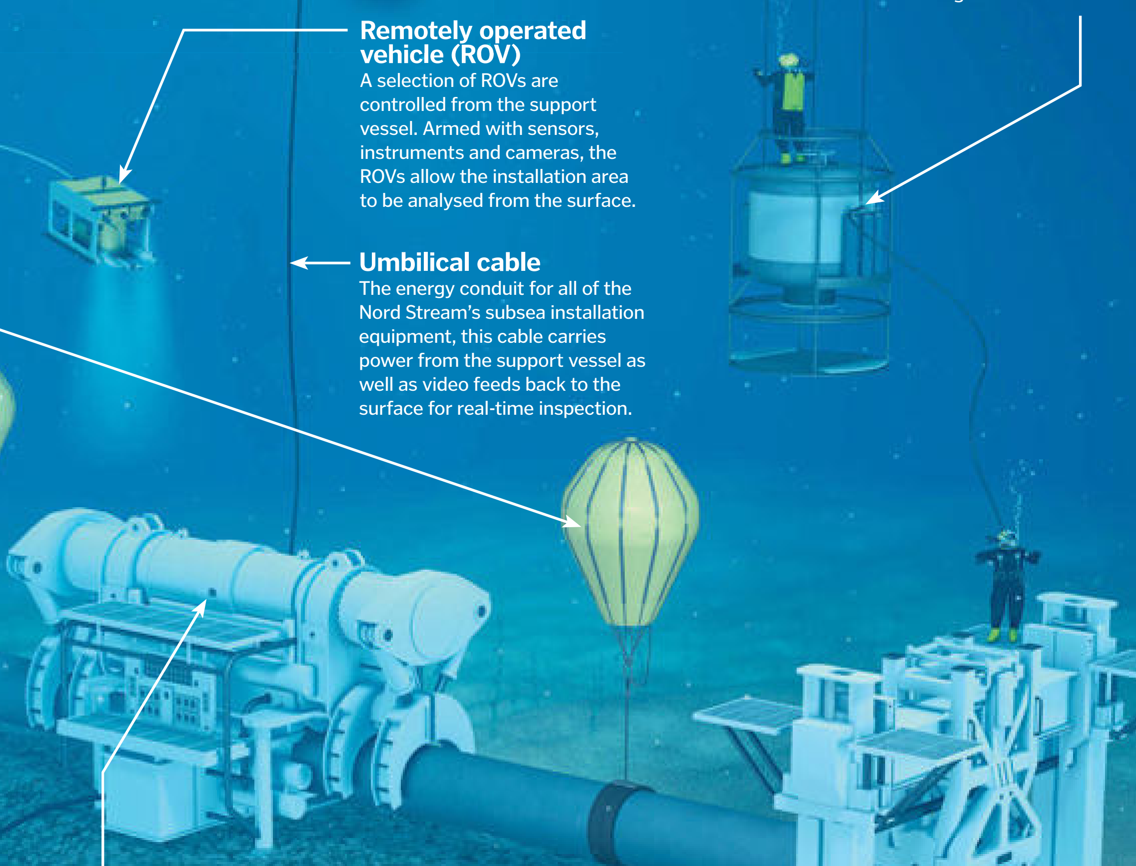
2008 June 2008 sees the first batch of pipes delivered to the Kotka distribution centre in Finland (right).

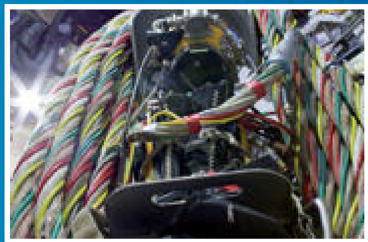


2010 Pipes begin to be delivered to the Nord Stream's three laybarges and, soon after, pipe laying commences.

2011 The gas for line 1 of the pipeline is switched on in November. Line 2 goes active a year later.

DID YOU KNOW? *The total construction cost of the Nord Stream was £6.4b ($10.1b)*



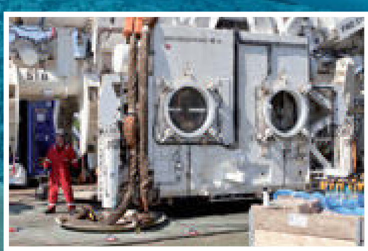


Diving bell
A transportation unit for the dive team, the diving bell can carry three people from the diving station to the subsea installation area. It has oxygen tanks that allow the divers to work in eight-hour shifts.

Remotely operated vehicle (ROV)
A selection of ROVs are controlled from the support vessel. Armed with sensors, instruments and cameras, the ROVs allow the installation area to be analysed from the surface.

Umbilical cable
The energy conduit for all of the Nord Stream's subsea installation equipment, this cable carries power from the support vessel as well as video feeds back to the surface for real-time inspection.

Welding habitat
A dry dock for the dive team as well as an industrial-scale welding machine, the welding habitat is responsible for joining segments of pipe. It is set up in-situ but controlled and powered from the support vessel.



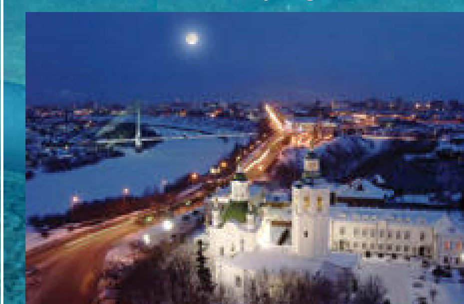
Environmental concerns

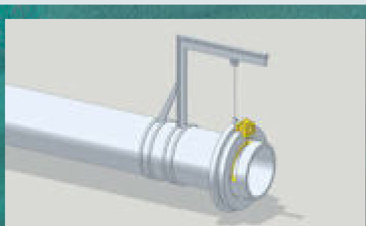
Laying millions of tons of concrete and steel on the Baltic Sea's seabed was not only an epic logistical challenge but also an environmental one. The potential effect to irreversibly damage the seafloor during the laying of a pipeline on this scale can be massive, displacing ecologies of ocean wildlife, injecting huge quantities of silt into the water and destabilising the landscape.

As such, prior to the laying of the pipeline more than 40,000 kilometres (24,850 miles) of geophysical surveys were conducted, with thousands of regions inspected and catalogued. This allowed the optimal route to be established in order to mitigate damage. In addition, to safeguard the sea since the installation, an environmental monitoring programme has been initiated that, with a fleet of specialist vessels including remotely operated vehicles (ROVs), will assess the water quality, seabed recovery and local fish, bird and mammal populations.

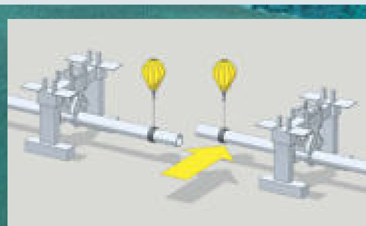
Siberian supply

The gas for the Nord Stream pipeline comes from the Yuzhno-Russkoye oil field in Tyumen Oblast, Russia. The pool of gas lies about a kilometre (0.6 miles) below the region's surface where there is estimated to be in excess of 1 trillion cubic metres (35 trillion cubic feet) of natural gas, with an additional 5.7 million tons of proven oil reserves. Currently there are 26 gas wells in operation at Yuzhno-Russkoye, extracting more than 15 million cubic metres (530 million cubic feet) of natural gas per day, the majority now flowing the 2,415-kilometre (1,500-mile) distance to Vyborg.

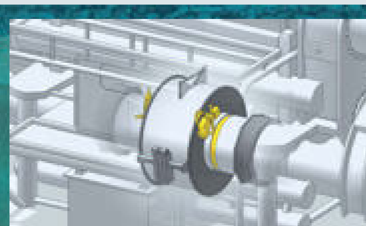




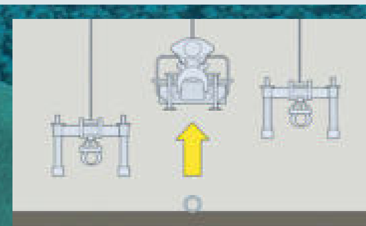
4. Bevelling
A bevelling machine gives both pipe ends a smooth finish. Their surfaces are measured to ensure they are uniform.



5. Lift
Three pipe-handling frames (PHFs) are used to lift and shift the pipe segments into position – vertically or horizontally.



6. Weld
The segments are then welded together in the welding habitat. Post-weld, the join is inspected using ultrasonic tests.



7. Retraction
Once the welded area has been signed off, the welding habitat is removed, shortly followed by the PHFs.

8.4m

WORLD'S BIGGEST 'BINOCULARS'

The Large Binocular Telescope (LBT) located on top of Mount Graham in Arizona, USA, employs two 8.4-metre (27.5-foot) mirrors to view the sky. While it might look like a giant pair of binoculars at first glance, it's technically an optical telescope.

DID YOU KNOW? The idea of binoculars was explored shortly after the telescope was invented in the early-17th century

Binoculars in focus

Learn about the precise engineering that goes into these instruments to bring distant objects up close

Binoculars work like a pair of matching telescopes, except they provide a magnified stereoscopic view of faraway objects. Their main advantages over a single lens monocular (telescope) is that they provide depth perception, they're more comfortable as they allow viewing with both eyes and the visual acuity is better because the brain has two sets of visual data to process.

The basic job of binoculars is to prescribe a folded path for the light entering the objective lens through to the eyepiece, and ultimately the operator's eye, so that the appropriate magnification can be achieved without increasing the overall length of the binoculars.

Each of the lenses has a pair of reflecting prisms inside that re-invert (ie flip and reorient) the image received by the lens. The most common type of binoculars incorporate Porro prisms (named after their Italian inventor, Ignazio Porro). However roof, or Dach, prisms are being used in some newer models that allow for a straight profile, with the eyepiece in line with the objective lens (as found in more compact binoculars). They're more comfortable and easier to manage than Porro-prism types, but need more careful aligning and lose more light, plus are generally more pricey than Porro-prism instruments.

Binocular optics are generally described by two figures. For example, the 10 in a 10x42 pair of binoculars refers to the magnification, while the 42 refers to the diameter of the objective lens in millimetres.

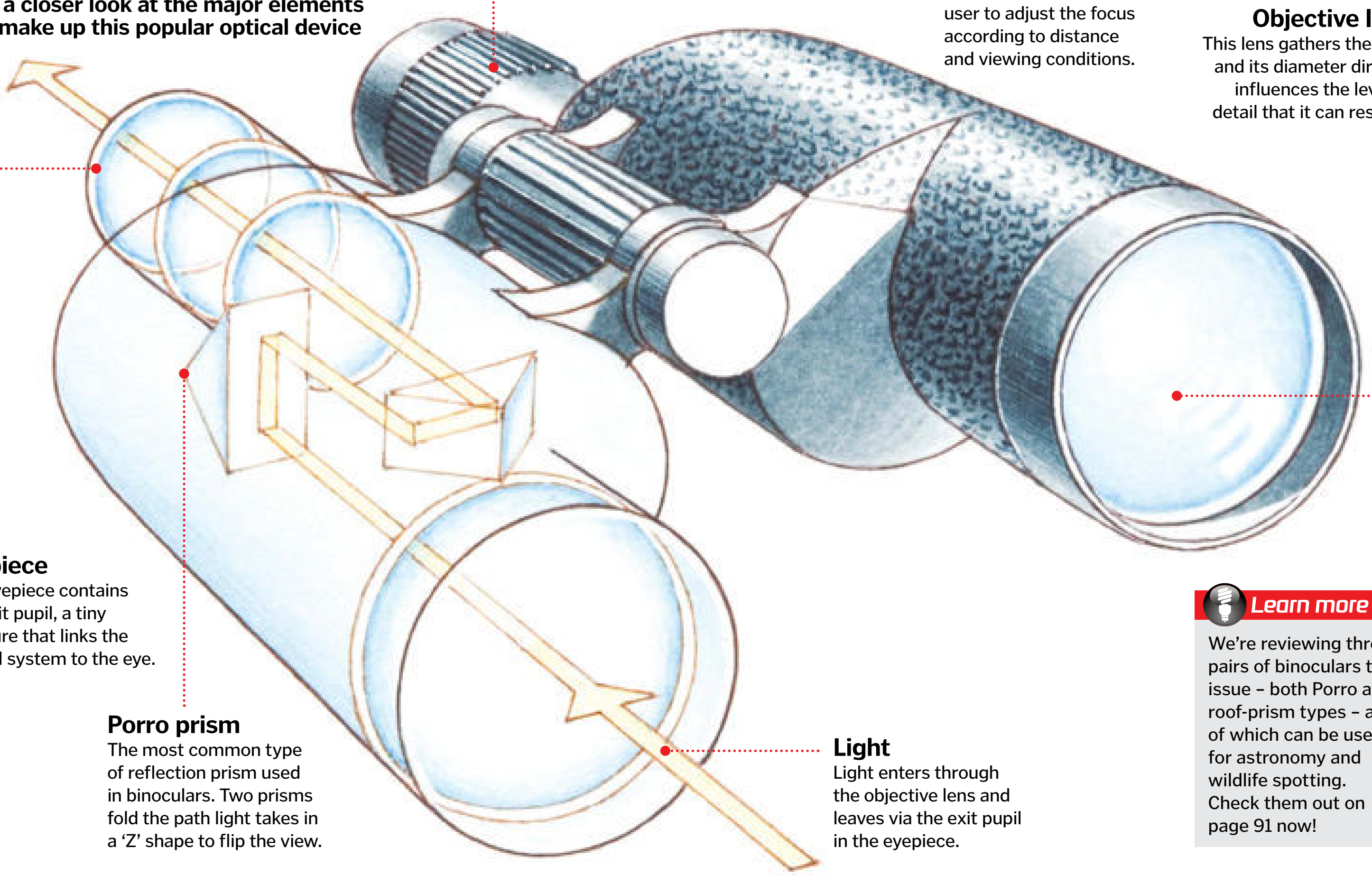
Binocular tech under the microscope

Modern binoculars employ a number of optical technologies in order to improve visual performance. The most common are the different optical coatings: a phase-correction coating on the surface of a roof prism, for instance, is used to compensate for the reduction in contrast and resolution that compact binoculars are known for. Anti-reflective coatings on every optical surface in certain binoculars can improve image contrast, while mirror coatings of aluminium or silver are used in some models of roof-prism binoculars to reduce the amount of light that is lost.

Binoculars which have a high degree of magnification may include some form of image stabilisation too. This is used because even the slightest tremor in the hands can significantly distort the image. These are often powered mechanisms driven by gyroscopes that dampen the effects of small, unintentional movements (see page 34 for more detail), although image-stabilisation technology tends to increase both the weight and price-tag of the binoculars.

Binocular breakdown

Take a closer look at the major elements that make up this popular optical device



Focus wheel
This wheel allows the user to adjust the focus according to distance and viewing conditions.

Objective lens
This lens gathers the light and its diameter directly influences the level of detail that it can resolve.

Eyepiece
The eyepiece contains the exit pupil, a tiny aperture that links the optical system to the eye.

Porro prism
The most common type of reflection prism used in binoculars. Two prisms fold the path light takes in a 'Z' shape to flip the view.

Light
Light enters through the objective lens and leaves via the exit pupil in the eyepiece.

Learn more
We're reviewing three pairs of binoculars this issue – both Porro and roof-prism types – all of which can be used for astronomy and wildlife spotting. Check them out on page 91 now!

"Analogue joysticks are used for programs where a much greater range of movement is required"

How does a gaming joystick work?

What tech is packed inside a joystick and how does it help you stay in control of a videogame?

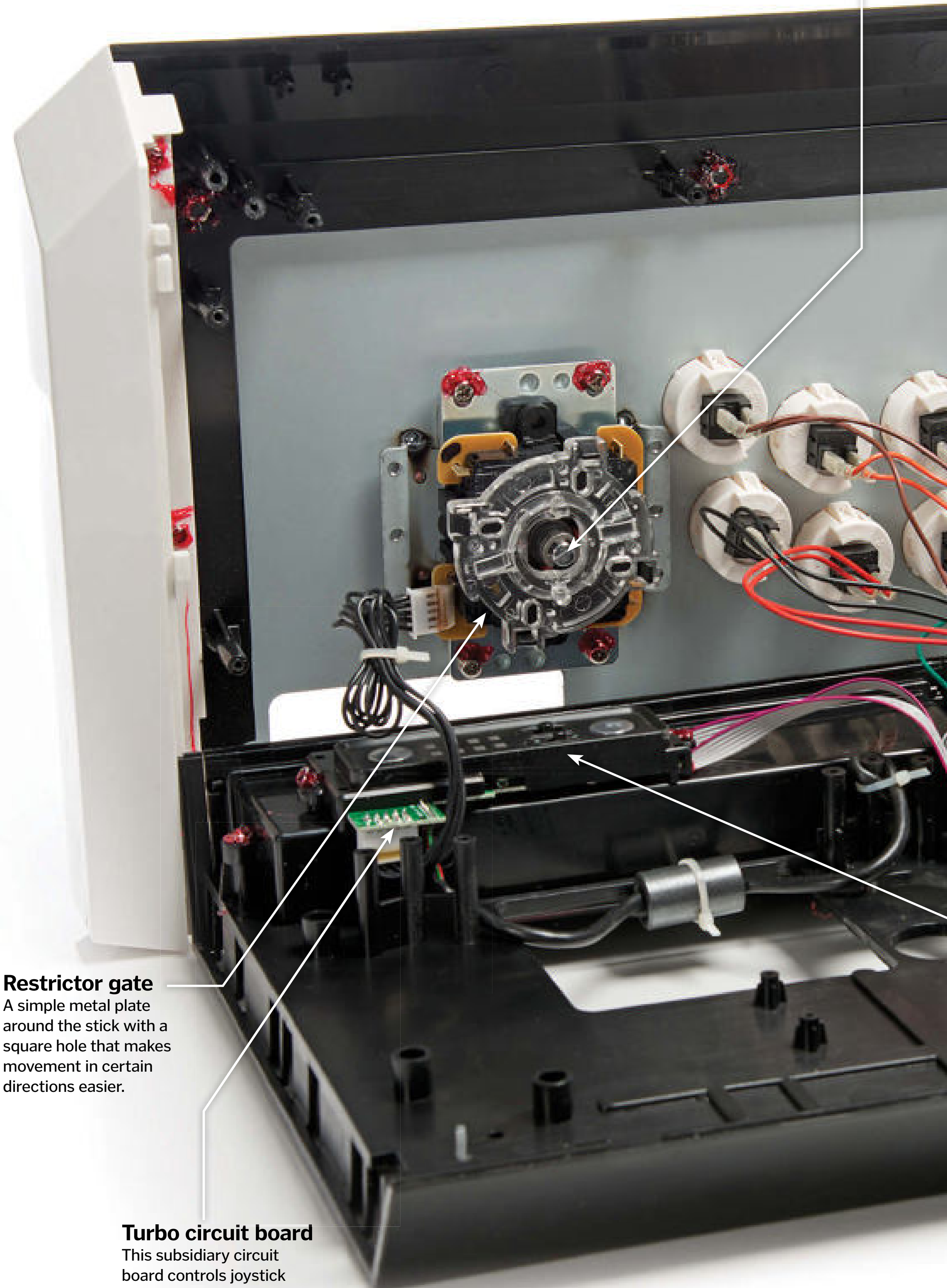
Joysticks essentially translate the movement of your hand into a digital format that a piece of software can then interpret to perform an action. They're used in a number of ways, from flying supersonic aircraft to controlling wheelchairs – to name just two – however joysticks are probably most commonly encountered as a major element of people's gaming systems.

Simple joysticks, such as the one used to control games on the early Atari consoles, employ electric switches to detect the direction you are holding the stick in.

Inside the base is a printed circuit board with contact terminals arranged around the bottom of the stick. While the joystick is in a neutral state (ie at the centre), or the stick isn't pressing the contacts into the 'on' position, the terminals cannot complete the electric circuit.

The gap in the circuit is closed when the terminals are pushed on, pressing a metal disc onto the board. The console then detects the charge on the wire and executes the appropriate action, whether that's moving left, right, up, down, diagonally or something completely different, depending on how the software interprets it. The buttons on the joystick – often used for actions other than movement – work in much the same way.

Analogue joysticks are used for programs where a much greater range of movement is required – like flight simulators. Instead of pressing buttons to complete circuits, the bottom of the stick slots into two shafts – one that pivots on the X axis and another on the Y axis – with springs that return the stick to a central position when released. A pair of potentiometers (variable resistors) track the location of these shafts and thus determine the position you're holding the joystick in.



Joystick
This uses four microswitches: right, left, up and down. Diagonals are determined when two switches are depressed at the same time.

Restrictor gate
A simple metal plate around the stick with a square hole that makes movement in certain directions easier.

Turbo circuit board
This subsidiary circuit board controls joystick LEDs and turbo switches.

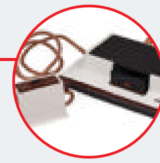
KEY DATES
JOYSTICK HISTORY

1926
The US Navy patents a two-axes joystick for use with remote-controlled aircraft.

1944
In Germany there's a patent for electric joystick anti-ship missiles and a guided munitions system.

1963
Beyond the RC model aircraft industry, joysticks begin to be used in powered wheelchairs such as the Permobil.

1972
The first games console, the Magnavox Odyssey (right), ships with an early form of gaming joystick.



1977
Atari launches the Atari 2600 home console, with a distinctive one-button joystick controller.

DID YOU KNOW? *Joysticks were around for more than 40 years before videogames were invented*

Joystick teardown

The Street Fighter IV TE FightStick is a specialist joystick that uses traditional switch technology

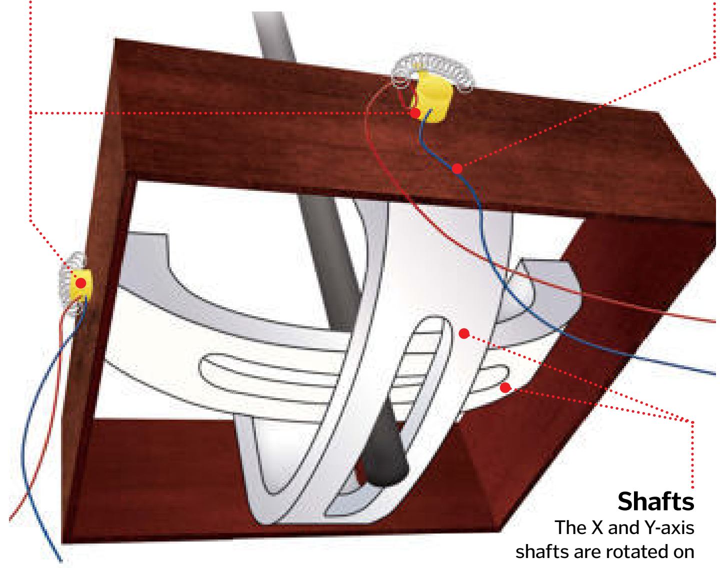
Control switch
A switching feature for this joystick allows you to lock buttons and apply 'turbo' functionality.

Main circuit board
Contains the processing elements of the joystick and circuit wiring for the buttons.

Terminal block
An intermediary piece of circuitry that connects buttons to the main circuit board.

Potentiometers
As the shafts are moved, contact arms on the pots move along a spring and alter the level of resistance.

Circuit wiring
As the circuit resistance is increased or decreased, a capacitor is charged more quickly or slowly accordingly.



Shafts
The X and Y-axis shafts are rotated on their hinges whenever the stick is moved.

The role of potentiometers

In an analogue joystick, as the base of the stick moves along the track of a shaft, a potentiometer (or pot) increases or decreases the resistance of the current in the X or Y-axis circuits accordingly. As opposed to the binary on and off state the contact terminals provide in a digital joystick, pots give an analogue range from the minimum value to the maximum value, depending on whether the stick is being pulled at its minimum range, its maximum range or somewhere in between. This signal still needs to be transformed into a digital numerical value though. A basic analogue-to-digital converter uses the voltage from the potentiometers to charge a capacitor, where a circuit with maximum resistance will charge more slowly than one with less resistance. By measuring the length of time the capacitor takes to charge fully, a numerical value can be ascertained.

Advanced joysticks

In old analogue joysticks the analogue-to-digital conversion is handed over to the console or computer, requiring the system to continuously request data from the joystick, known as 'polling', to detect its current position. This can be a drain on system resources, so newer joysticks include an analogue-to-digital converter chip that translates the signal for the computer.

Some of the latest joysticks avoid this problem altogether by using optical technology. The shafts are connected to slotted wheels, each placed between an LED with a photocell on the other side. When the wheel turns and a slot lines up with the cell, the light from the LED causes it to generate a current, switching off once it's blocked again. Cutting-edge joysticks like the Saitek X-65F (pictured) don't even have moving parts – instead they respond to pressure exerted on the stick, which is exactly the same system found in modern fighter jet planes.

> "Most image stabilisation tech uses a movable lens that adjusts depending on the incoming light"

Image stabilisation

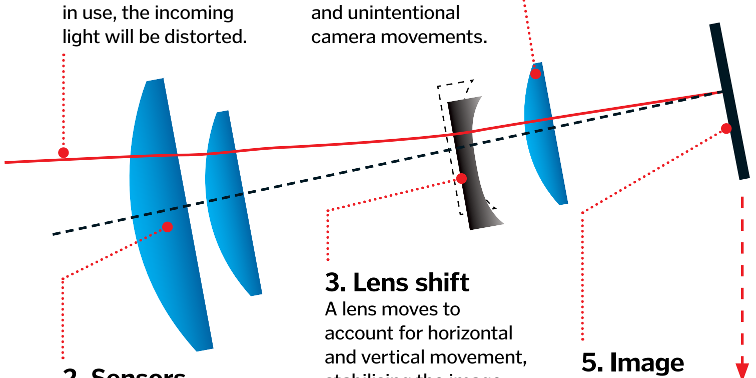
How this clever technology is used in cameras to keep our photos blur free

Image-stabilisation technology is used to eradicate unintentional movements when taking a picture so that the final image is crisp and clear. Most image-stabilisation technologies employed in cameras use a movable lens that adjusts depending on the incoming light. Under normal conditions, the light from the image passes straight through the lenses in the camera. However, if the camera is moved while the photograph is being captured, an internal lens detects vibrations using gyroscopic sensors and can move and direct the optical path of the incoming light correctly to the final sensors.

The technique can be used to allow for pan and tilt (yaw and pitch movements) and this is particularly useful when taking images with long exposures. Indeed, image stabilisation can help exposures that are up to 16 times longer than a standard snap to stay in focus.

Ready, steady, shoot!

Take a look at Canon's Image Stabilizer (IS) tech in focus



1. Shaky start
If the photographer moves the camera while in use, the incoming light will be distorted.

2. Sensors
When the shutter is pressed halfway, gyroscopic sensors detect vibrations caused by shaking.

3. Lens shift
A lens moves to account for horizontal and vertical movement, stabilising the image.

4. Correction
The tech can discern between intentional and unintentional camera movements.

5. Image
The final shot is rendered clearly on the image plane, eradicating flaws caused by shaking.

Without image stabilisation

With image stabilisation

How do straighteners flatten hair?

The red-hot gadget that can take the kinks out of curly hair explained

When human hair lacks enough natural moisture, or when it's exposed to high or low humidity, it may become brittle and/or rough. To this end, hair straighteners, or flat irons, can be used as a quick and easy way to make frizzy and curly hair temporarily straight.

Curly hair is often caused by positively charged hydrogen bonds between the keratin proteins. Flat irons use intense heat to break these bonds. This heat is transferred to the aluminium and ceramic plates of the straighteners – between which the hair is clamped – before stroking downwards. A negative charge is also often run through the irons, which aids in breaking the bonds.

The curlier the hair, the more heat will be required to straighten it as more bonds are present. Too much heat, though, can burn and damage the hair, so these devices must always be used with care.

Flat irons up close

What's going on inside this popular hair-styling gizmo?

Tapered
The angled surface of flattening irons allows hair to be straightened closer to the roots, which reduces damage.

Hinge
A spring-loaded hinge enables the two parts of the straighteners to be brought together in the user's hand.

Plate
Lightweight aluminium in the plates allows for rapid heat transfer, while ceramic prevents hair sticking to them.

Element
Heating elements within the device are thermostatically controlled to direct the required heat into the plates.

Protection
A thin material that is a good insulator, like plastic, is used at the edges of the plates to prevent the scalp from being burned.

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"An AFM uses a cantilever with an incredibly fine silicon tip that's usually micrometres long"

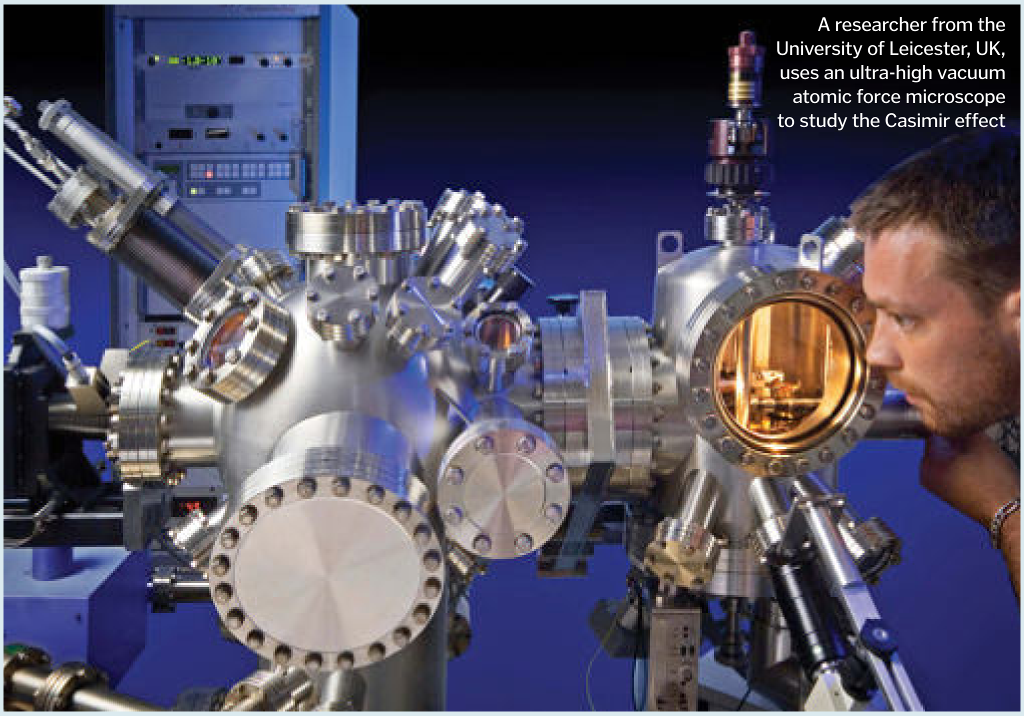
What are atomic force microscopes?

How do these instruments image samples too tiny for normal microscopes?

Atomic force microscopy (AFM) is a branch of scanning probe microscopy that includes several dozen ways of scanning the surface of a tiny specimen to create an image. It can resolve images of objects mere nanometres long, over 1,000 times sharper than the best optical microscopes.

An atomic force microscope uses a cantilever with an incredibly fine silicon tip, or probe, that's usually micrometres long and whose tip has a radius of under ten nanometres. The tip of the cantilever runs over the surface of the sample, making contact or maintaining a tiny distance depending on the settings dictated.

These microscopes can work in several modes that fall into two categories: static and dynamic. The cantilever is physically dragged over the sample's surface in static mode and the contours of the specimen are directly measured. In dynamic – or tapping – mode, on the other hand, the cantilever is oscillated and the varying forces that result from its interaction with the sample are recorded. The obvious advantage that dynamic mode has over static is that it can be used on 'soft' specimens, where contact might lead to degradation of both the sample and the tip.



A researcher from the University of Leicester, UK, uses an ultra-high vacuum atomic force microscope to study the Casimir effect

AFM: pros and cons

Scanning electron microscopy (SEM) is a different type of microscopy that deals with samples of a similar size to atomic force microscopy. AFM can boast certain advantages over SEM, but it also has some disadvantages.

AFM can create a 3D profile of the sample, unlike SEM's 2D results and the samples don't require any special coating either. This means specimens that might be changed or damaged by the SEM process (eg micro-organisms) can be studied. AFM can also be used in conjunction with other optical techniques and can yield higher resolutions even in liquid environments.

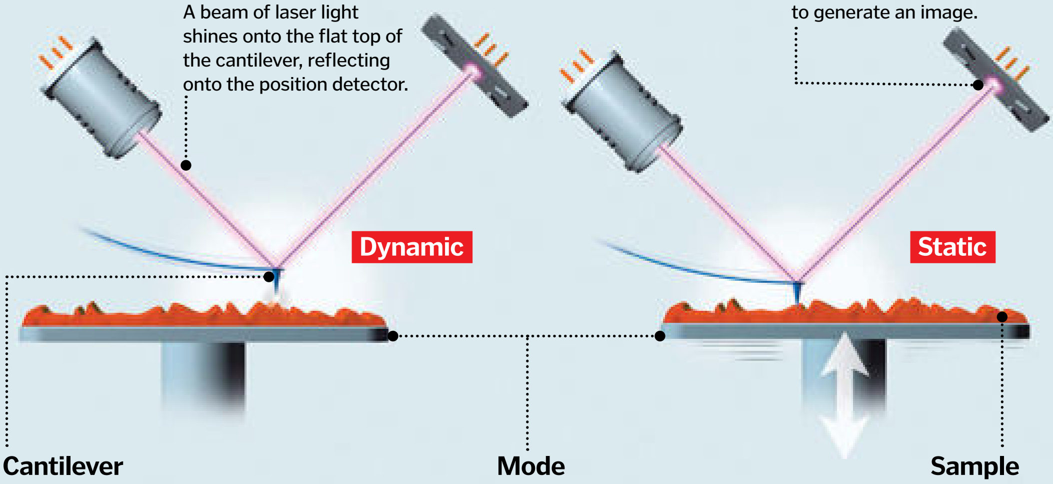
On the down side, AFM is limited with regard to the size of the sample scan image it can take – around 1,000 times smaller than the area SEM can capture in a single pass. Its scanning speed is slower too and an atomic force microscope can't measure samples with particularly steep topography unless it's specially modified.

Atomic force microscope up close

HIW homes in on the key parts of static and dynamic atomic force microscopes to reveal how they study minute samples

Position detector
A light-sensitive photodiode records changes in the position of the reflected laser beam. It is this data which is used to generate an image.

Laser
A beam of laser light shines onto the flat top of the cantilever, reflecting onto the position detector.



Cantilever
A cantilever (a lever fixed at one end) with a very fine tip is scanned across the surface of the sample.

Mode
The AFM can be set to either a static or a dynamic mode; in the latter the tip is vibrated as it passes over the specimen.

Sample
The microscopic peaks and troughs in the sample deflect the cantilever towards or away from the surface.

"Currently smart glass is being incorporated into offices, houses and vehicles"

The science of smart glass

How a little electricity can change the tint of glass in an instant

Smart glass is a general nickname for glass that is electrically switchable between tints or shades. There are several different types of smart glass technology, however the most prolific are suspended particle devices (SPDs).

SPDs are sheets of glass that contain a matrix polymer film filled with crystalline particles encased in a carrier fluid. In their natural state these particles block light, with a non-uniform pattern preventing rays from passing properly.

Key to this tech is that when electricity is passed through the particles – via a pair of electrodes mounted to the polymer matrix – the current forces the particles to align in a uniform pattern. This allows a far greater quantity of natural light to penetrate the glass, granting it a transparent quality and high light value.

Currently smart glass is being incorporated into offices, houses and vehicles – like the Mercedes-Benz 2012 SLK Roadster (pictured). Its popularity stems from the privacy it provides and also its heat-retention qualities, with shaded glass offering significant reductions in heat loss and thus overall energy savings.

Inside the glass that can adapt

We shed some light on the fundamental elements in a sheet of smart glass

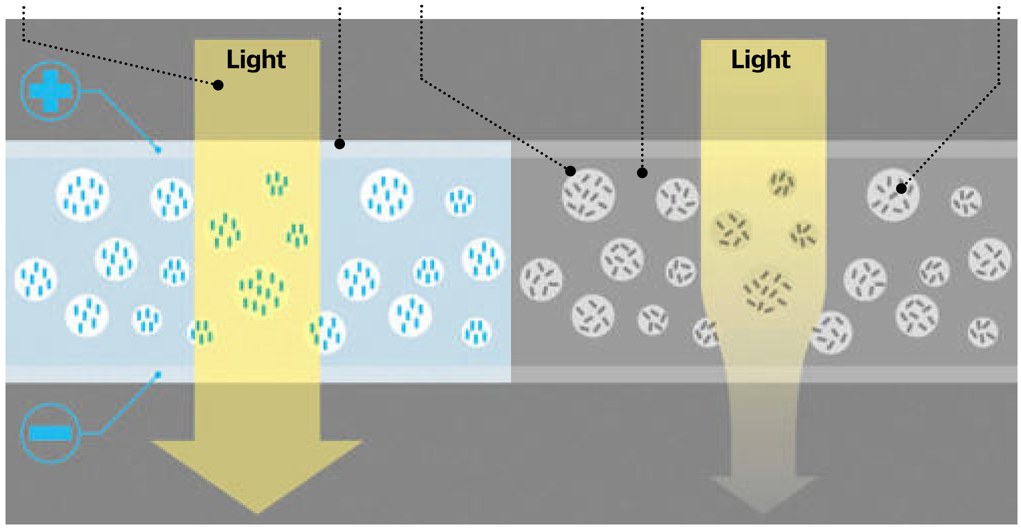
Light
Light rays entering the glass are blocked when no electric charge is present, but pass freely when the electricity is on.

Transparent electrode
Either side of the polymer matrix are two electrodes which, when activated, force the particles to align.

Carrier fluid
The light-absorbing crystalline particles are suspended within the film layer – a polymer matrix – by a carrier fluid.

Film sheet
The glass panel is coated/inserted with a film sheet. This polymer matrix film is filled with light-absorbing particles.

Particles
The crystalline particles are in a non-uniform pattern in their natural state, causing light rays to be partially blocked.



How do calculators do the maths?

Electronic calculators make use of an impressive array of tech to crunch the numbers

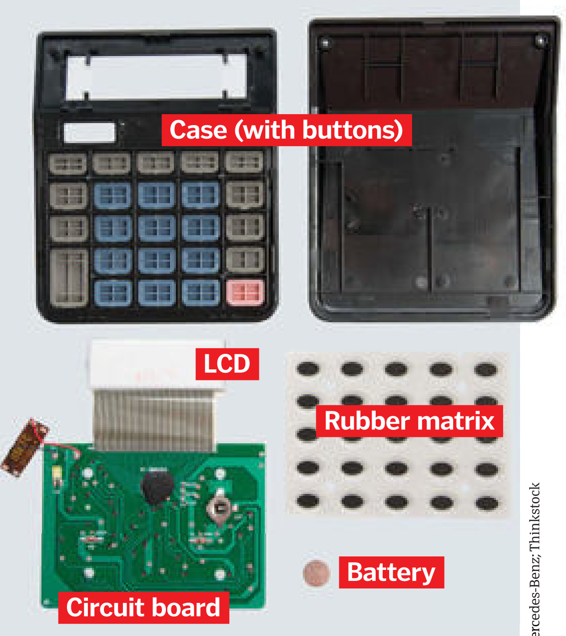
Tapping numbers into a calculator sure is easy, with your numerical query answered in seconds. However, with each sum a series of complex processes and components come into play.

Components first. A standard calculator includes a plastic casing, rubber button matrix, circuit board, single-chip CPU, battery array and liquid crystal display (LCD). More advanced models come equipped with a solar cell stack and/or integrated memory chips – the former used to charge the internal battery with the Sun's energy, and the latter to store advanced calculations or equations.

Now let's move on to the processes. Take a sum like '2 + 2'. When a user presses the 2 button on the rubber matrix, it deforms, forcing a bottom-mounted electrical contact onto the circuit board below and creating a connection. This causes electricity to flow to a pair of transistor switches on the board that convert the current into an on-off binary equivalent (a combination of 1s and 0s).

Next, when the '+' button is pressed, the inputted 2 is stored in its binary form by the calculator's CPU, before resetting the input state to a receptive position. After the next 2 is inputted, the CPU sends both numbers to a logic gate as soon as the '=' sign is hit.

Logic gates are electrical circuits with two inputs and only one output which execute logical operations that, in this context, are the adding, subtracting, multiplying and dividing processes. The inputs are sent in binary form to a logic gate, processed and then outputted as a single output – ie the number 4 in binary code. Finally, the answer is routed to the device's LCD, where the digit 4's binary is converted into segmented, illuminated lines that can be read off the display bar.



HEAD2HEAD GAMING HEADSETS

1. BASIC

Roccat Kave 5.1
Producing 5.1 surround sound through a series of 40-millimetre (1.6-inch) speakers, the Kave 5.1 offers non-simulated sound from the front, rear and sides.

2. BETTER

Razer Chimaera 5.1
With six channels of wireless surround sound over a 5.8-gigahertz band, the Chimaera offers great audio for Xbox 360 users.

3. BEST

Logitech G35 7.1
Providing a whole eight channels of surround sound wirelessly, the G35 comes with on-ear controls and is one of the most advanced headsets money can buy.

DID YOU KNOW? Currently, commercial headphones support up to eight channels, producing a level of audio known as 7.1

Exploring 5.1 headphones

How do these cutting-edge headsets create an immersive audio experience?

There are two types of 5.1 surround-sound headphones: simulated and non-simulated. Non-simulated, or 'true', 5.1 headphones use multiple speakers embedded in the headphones' two earpieces to generate multi-angle sound placement, while simulated varieties employ complex sound-processing algorithms to create the same effect.

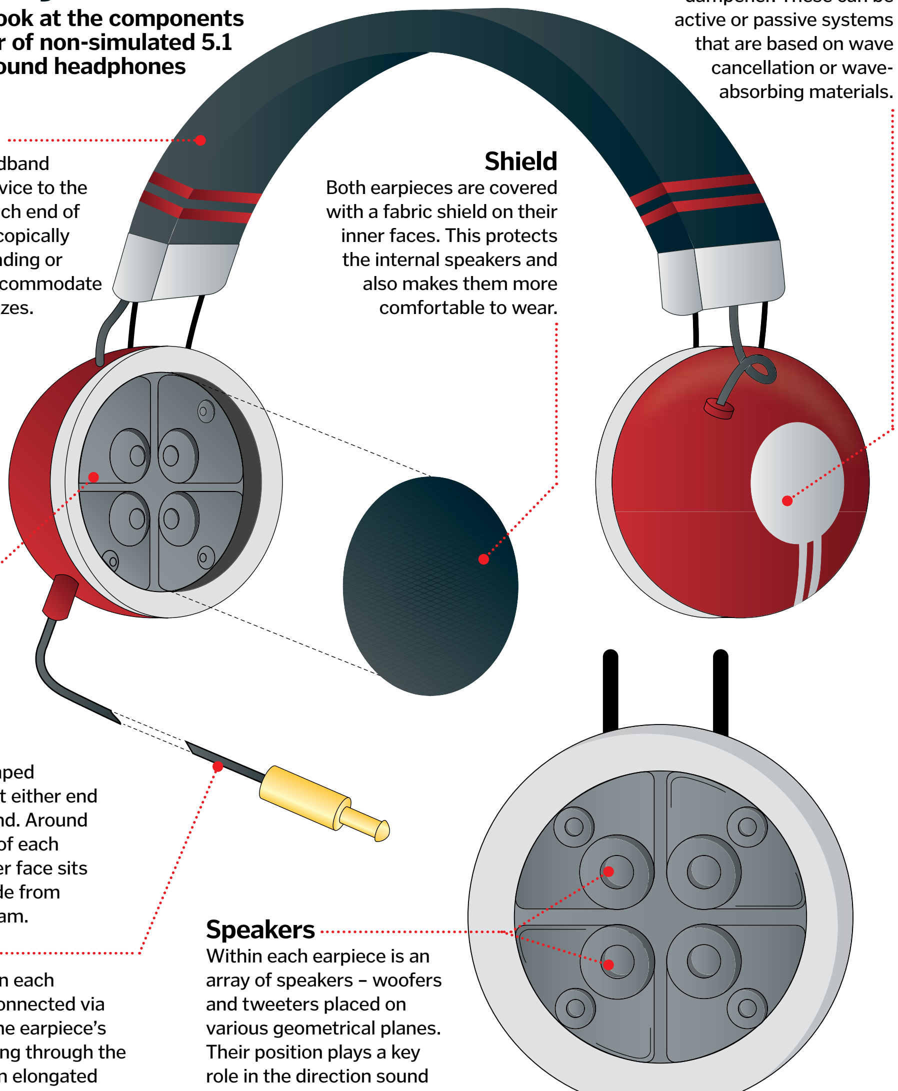
Taking non-simulated headphones first, the surround sound comes from six channels – it is not five channels, as the '.1' low-frequency channel (subwoofer) is counted – with signals received from the decoder/player split across each earpiece. This arrangement typically generates more accurate sound placement due to each channel having an individual driver.

Simulated 5.1 headphones, meanwhile, achieve directional sound placement differently, relying on only one speaker per earpiece and only one driver per channel. Multi-direction sound placement comes courtesy of an in-headphone or externally connected pre/mix-amp. This amp employs mathematical algorithms to divide the received stereo signal into distinct segments, before it reaches the earpieces. In doing this, the amp ensures that audio from the speakers hits specific parts of the ear in a certain order. This generates the illusion that specific sounds are coming from the front, rear or side.

While 'true' 5.1 headphones do generally produce better sound placement, due to the smaller scale of their internal speakers, they rarely boast the audible range of simulated or non-surround-sound headsets, which have larger single speakers in each earpiece.

Anatomy of a 5.1 headset

We take a look at the components inside a pair of non-simulated 5.1 surround-sound headphones



Headband
An arched headband secures the device to the user's head. Each end of the band telescopically extends, expanding or shrinking to accommodate various head sizes.

Shield
Both earpieces are covered with a fabric shield on their inner faces. This protects the internal speakers and also makes them more comfortable to wear.

Dampener
In each earpiece's inner face lies an acoustic dampener. These can be active or passive systems that are based on wave cancellation or wave-absorbing materials.

Earpiece
Two dome-shaped earpieces sit at either end of the headband. Around the periphery of each earpiece's inner face sits an earpad made from deformable foam.

Cabling
The speakers in each earpiece are connected via wires – with one earpiece's cables extending through the headband to an elongated cord that terminates in a jack.

Speakers
Within each earpiece is an array of speakers – woofers and tweeters placed on various geometrical planes. Their position plays a key role in the direction sound is received by the ears.

© Logitech; Roccat Studios; Razer

> "Ambient cooling of the offices negates the need for energy-hungry air-conditioning units"

The Pearl River Tower

This 71-storey tower block is being touted as the greenest skyscraper on Earth, but what makes it so energy efficient?

While many buildings flaunt their green credentials by incorporating a single piece of in-your-face, eco-friendly technology into their design, the Pearl River Tower in Guangzhou City, China, goes much further, drawing together a bevy of cutting-edge systems to jump closer to an almost zero-energy building (ZEB) – the holy grail for today's architects.

This is achieved first and foremost through its 309-metre (1,014-foot)-high sculpted faces, which redirect wind to four openings at its mechanical floors. Here, the wind is drawn through the building's body and into a series of turbines, which combined generate electricity for the offices within. In addition to driving turbines, the wind that is pulled in is also rerouted throughout the tower's ventilation system, with the air being filtered through the building's floor and ceiling spaces. This ambient cooling of the offices negates the need for energy-hungry air-conditioning units in hot weather, which saves a considerable amount of electricity.

The entire building is also fitted with an advanced, double-glazed skin. The outer layer of this can be penetrated by heat from sunlight, however the inner layer cannot, causing the rays' heat to become trapped and not enter the interior. This trapped heat therefore rises through the skin's cavity to heat exchangers where it is absorbed and stored for reuse in both energy generation and heating processes.

Lastly, large solar panels are installed on the building's exterior roof, which directly absorb sunlight for generating energy. This energy is used to provide power for the skyscraper's perforated metal window blinds, which automatically track the Sun and open/close to minimise heat loss or to moderate ambient office temperature. The blinds themselves are also equipped with photovoltaic cells, so even when they are closed, the Sun's energy is still being efficiently harvested.

Making use of wind, sunlight and an innovative design, the Pearl River Tower has won a number of awards for its superior energy efficiency

THE STATS
PEARL RIVER TOWER

HEIGHT 309m | NUMBER OF FLOORS 71 | TOTAL FLOOR AREA 212,165m²

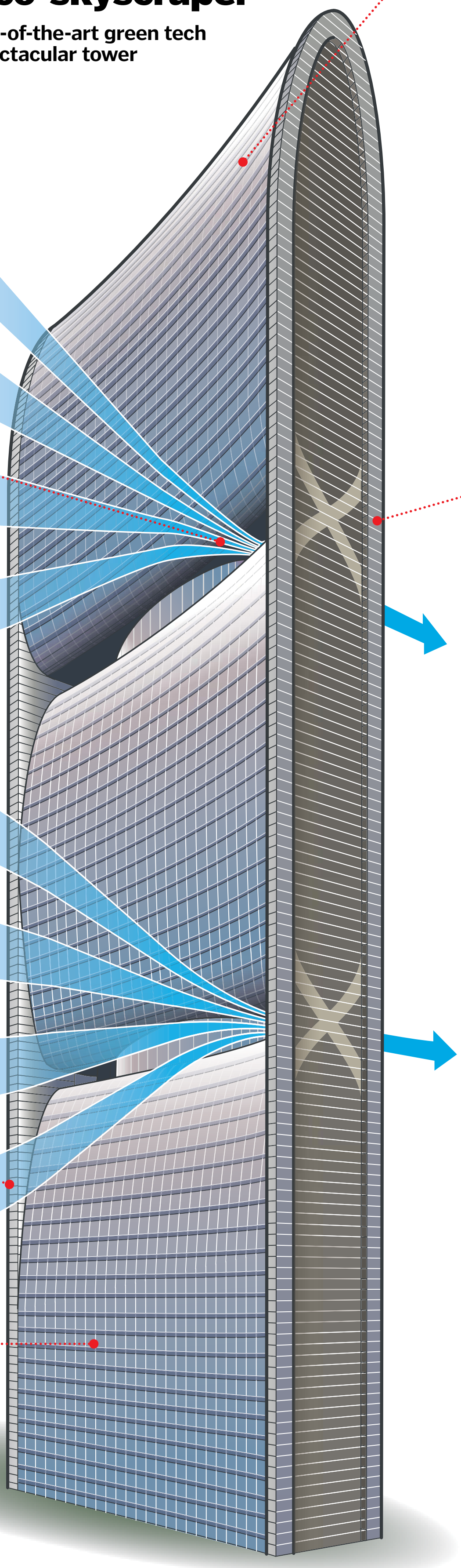
SITE AREA 10,635m² | NUMBER OF ELEVATORS 29 | YEAR OPENED 2012

DID YOU KNOW? *Famous American architect Gordon Gill was the lead designer behind the Pearl River Tower*

Anatomy of an eco-skyscraper

Take a look at some of the state-of-the-art green tech that's been packed into this spectacular tower

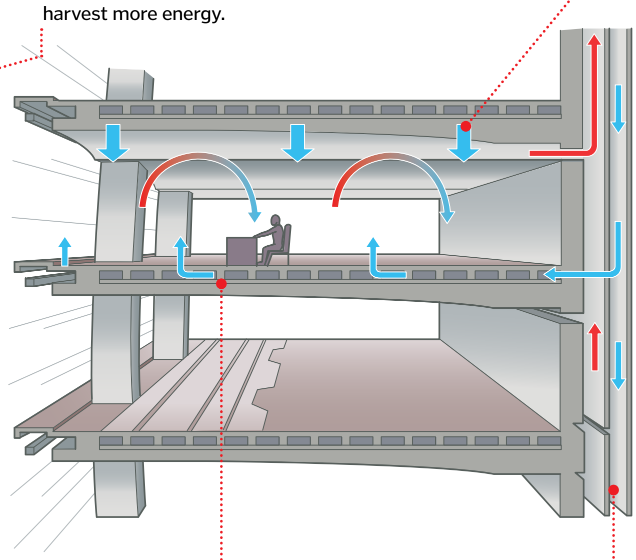
Turbine inlet
Prevailing northerly and southerly winds are drawn through four inlets in the building's façade (two on either side) into a series of wind turbines. These produce electricity for use in the building's offices.



Solar panels
The roof of the Pearl River Tower is fitted with a large, curved array of solar panels. These panels soak up sunlight and generate electricity – the energy being used to power the building's automatic blinds.

Ventilation system
Air drawn into the building through its four main inlets is also rerouted into the structure's ventilation system. This can then be used to cool the ambient temperature of the office space so air conditioning is not needed in the summer.

Vertical axis
The vertical axes of the tower combine to grant it a revolutionary curvilinear form that both funnels approaching wind into the façade's turbine inlets as well as exploiting the area's solar path to harvest more energy.



Triple glazing
On the eastern and western faces (the thin ends) a triple-glazed coating is used to prevent heat loss from within and excess heat from the Sun's rays entering.

Heat exchanger
Installed in the tower's mechanical floors, the heat exchangers receive heat from the double skin cavities and converts it for reuse as electricity or stores it for later use in underfloor heating.

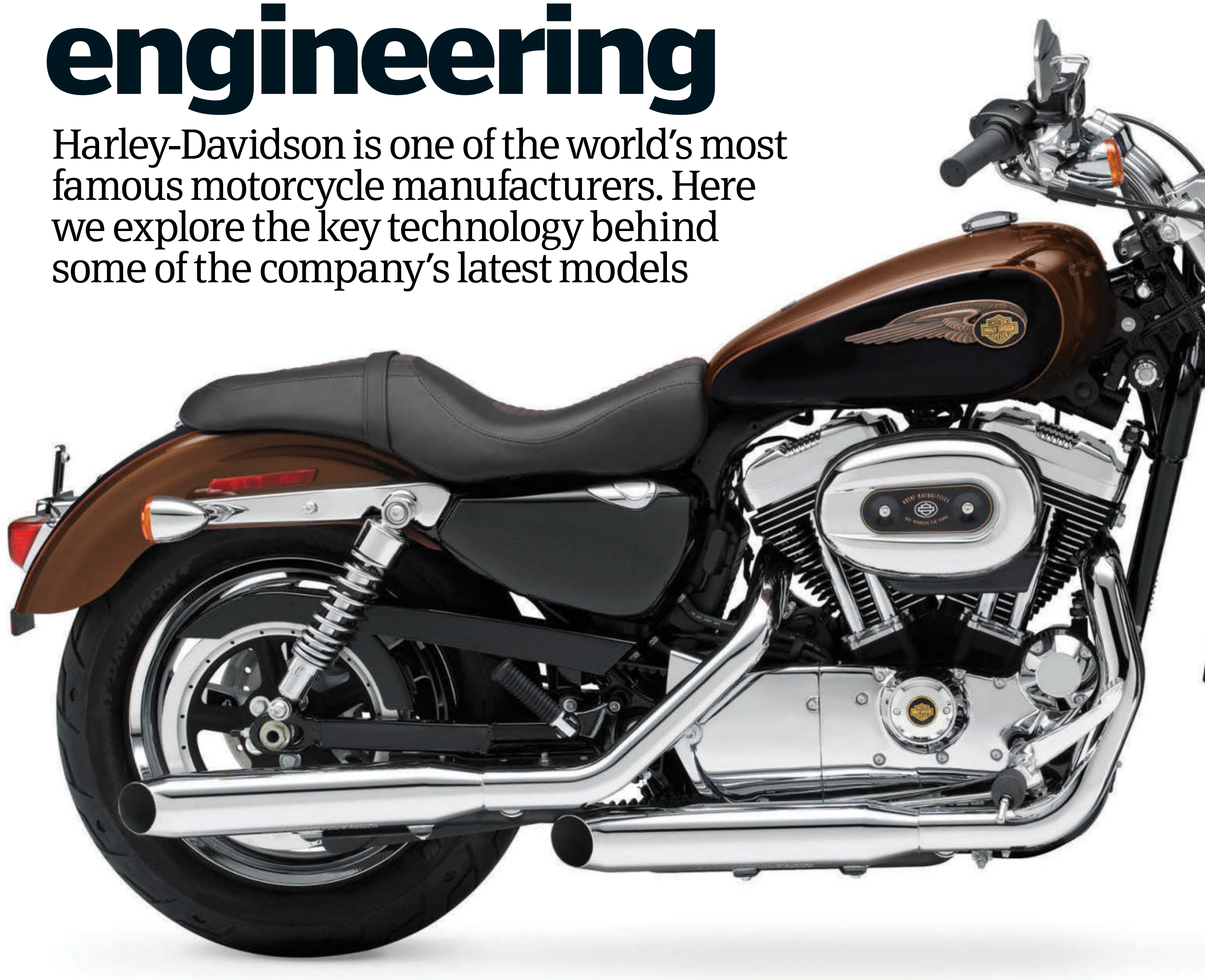
Double skin
On the building's two vertical axes a two-layer façade traps hot air generated by the Sun in a thin cavity. The hot air, rather than seeping into the office space, rises to heat exchangers located on mechanical floors.

Photovoltaic cells
A photovoltaic energy capture system is integrated into the Pearl River Tower's external shading system (blinds) and glass outer skin. As with the solar panels, this system can convert sunlight into electricity.

Turbine technology
The turbines equipped between the mechanical floor spaces of the Pearl River Tower can generate in excess of four per cent of the building's total power draw annually. This is due to the turbines being specifically designed to work across a variety of wind speeds, ranging from small flows moving at around eight kilometres (five miles) per hour, right up to intense 225-kilometre (140-mile)-per-hour surges. Due to the building's orientation, the prevailing winds from the north and south of Guangzhou City are harnessed, with the tower's curvilinear form funnelling indirect wind flows into the turbine inlets.

Classic motorbike engineering

Harley-Davidson is one of the world's most famous motorcycle manufacturers. Here we explore the key technology behind some of the company's latest models



Harley history

See how one of the planet's most celebrated motorbike makers has evolved over the last 110 years…

1901
Blueprint
William S Harley completes the blueprint for a single-cylinder 'motorised cycle' engine.

1908
Police
The first bike is used by the police force in the city of Detroit, Michigan.

1910
Logo
The 'bar and shield' logo is used for the first time. Sensibly, it is quickly trademarked.

1911
V-Twin debut
The V-Twin engine is launched with mechanically operated valves. Within two years, most bikes made by the firm will use this engine.

Take two
1 The V-Twin engine was introduced in 1909, but it proved so troublesome that H-D later took it off the market to perfect the design. It was reintroduced in 1911.

45 degrees
2 Harley-Davidson has trademarked the 45-degree angle of its V-Twins. It is judged the best compromise between lots of torque and relative compactness.

Brand success
3 Harley-Davidson is now a world-famous brand with a cult following. Licensing the brand itself actually accounts for tens of millions of pounds in the company's overall revenue.

Easy Rider
4 A 1969 custom-built hardtail chopper was used in the popular *Easy Rider* film. Only the engine and the wheels were original Harley parts – the rest was tailor made.

Gone trucking
5 Ford introduced a special H-D iteration of its F-150 SUV pickup truck in 2000. This has proven so popular that the Ford F-150 Harley-Davidson Edition is produced to this day.

DID YOU KNOW? In 1921, a Harley-Davidson is the first motorcycle to win a race at an average speed of over 161km/h (100mph)

Harley-Davidson is a manufacturer synonymous with large-engine motorcycles and in 2013 is celebrating its 110th year. With their loud and distinctive two-cylinder engines, notable designs and onus on customisation, however, they are arguably viewed as a type of motorcycle in their own right, with the company carving out its own unofficial category within the market.

The Harley-Davidson range has traditionally been based around two types of motorcycle: one with smaller engines (the small twins) and one with larger motors (the big twins). In recent years, a more modern 21st-century variant has also been introduced, with technology developed in association with the supercar manufacturer Porsche, however the core range is the traditional two-cylinder motorcycle.

A Harley-Davidson bike contrasts starkly with your average sports bike. Dominated by Japanese brands such as Suzuki, Yamaha and Kawasaki, the sports bike is the antithesis of a Harley-Davidson – lightweight, compact and fitted with very highly tuned, extremely high-revving engines that produce incredible power outputs in relation to their size.

To compare, a Harley-Davidson 883cc (cubic centimetres) Evolution engine produces 41 kilowatts (55 horsepower) at 6,000 rpm (revolutions per minute) and 6.9 kilograms-force (50 pounds-force) of torque at 4,600 rpm. A 782cc Honda VFR800 of the same size, meanwhile, produces 80 kilowatts (107 horsepower) at 10,500 rpm and 8.1 kilograms-force (59 pounds-force) of torque at 8,750 rpm. This disparity is due to Harley-Davidson motorcycles being engineered to deliver easy-going – read: cruising at modest speeds – performance and lots of low-down torque.

Today, there are five basic model ranges of Harley-Davidson – four traditional ones and a new type that was introduced in 2001 which finally broke with the small twin/big twin tradition: the VRSC.

Mechanically, H-D bikes use large-diameter telescopic forks, rear coil over air suspension and a cradle-type single-spar frame, forming the backbone of the bike. The engine and components are mounted within the frame, and it also carries the pivot point for the steering head. Most Harley-Davidson motorcycles have a single-spar rear suspension whose pivot point is also mounted on the frame. Both the frame and the rear swingarm have been frequently redesigned over the years – the last time in 2009.

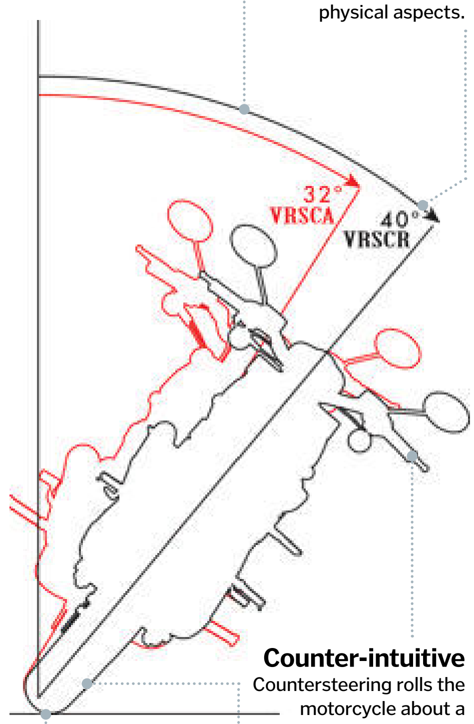
This type of construction contrasts with the twin-spar frames used on sports bikes, which is stronger and able to withstand the higher forces such machines generate. They use the engine as a stressed member, acting as the main load-bearing ▶

Working with physics

Bikes lean in corners to remain balanced and counteract the centrifugal force. The faster the corner, the steeper the lean…

Lean to turn
Even at slow speeds, a motorcycle must lean to turn. The frame lean angle is measured in degrees from the vertical through the centre line of the bike.

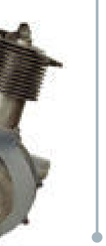
Degrees of lean
Some H-D motorbikes, like the VRSCR, have a greater lean angle than others. This is the result of bodywork design, weight distribution and other physical aspects.



Counter-intuitive
Countersteering rolls the motorcycle about a centre of gravity and results in lean to the opposite direction. Simply put, to corner a bike to the right, you must turn to the left.

Lean types
When a motorcycle is cornering, the 'visual' lean angle is greater than the 'system' lean angle. This is because the bike rolls on its tyre, offsetting the system lean axis sideways.

Tyre grip
The lateral cornering force (centripetal force) is provided by the grip of the tyres – this is what pushes the motorcycle into a corner. If grip runs out, the bike slides outwards.



1913
New premises
Harley-Davidson outgrows its original yellow brick factory – so a new five-storey plant made of red bricks is built.

1914
Racing glory
Harley enters its bikes in competitive racing for the first time. It will go on to become a very successful manufacturer.

1917
Military service
The United States enters World War I in 1917 – and Harley enters combat service for the first time. Around 15,000 Harleys are used in the conflict.

1920
Market leader
Harley-Davidson becomes the world's biggest motorcycle manufacturer: more than 28,000 machines are produced in this year alone.

1945
WWII
Harley-Davidson restarts civilian production at the end of World War II; it produced nearly 90,000 special WLA models for military use in this war.

"The modern VRSC range is a very advanced design based around a new 60-degree V-Twin engine"

component of the frame. This type of frame has been selected because it allows for far easier customisation and leaves the engine exposed.

The longest-running Harley-Davidson range still in production is the FL Touring series, which has been built since 1941, with a basic frame design that's been used since 1980. These are retro-styled motorcycles defined by their large clear windscreen, front fairing and large rear saddlebags. They have in the past been known for usually having a Citizens' Band (CB) radio fitted. The engine is a Shovelhead motor that's rubber mounted in the frame in order to soak up vibrations. The 'Big Twin' model of engine is used in Touring motorcycles.

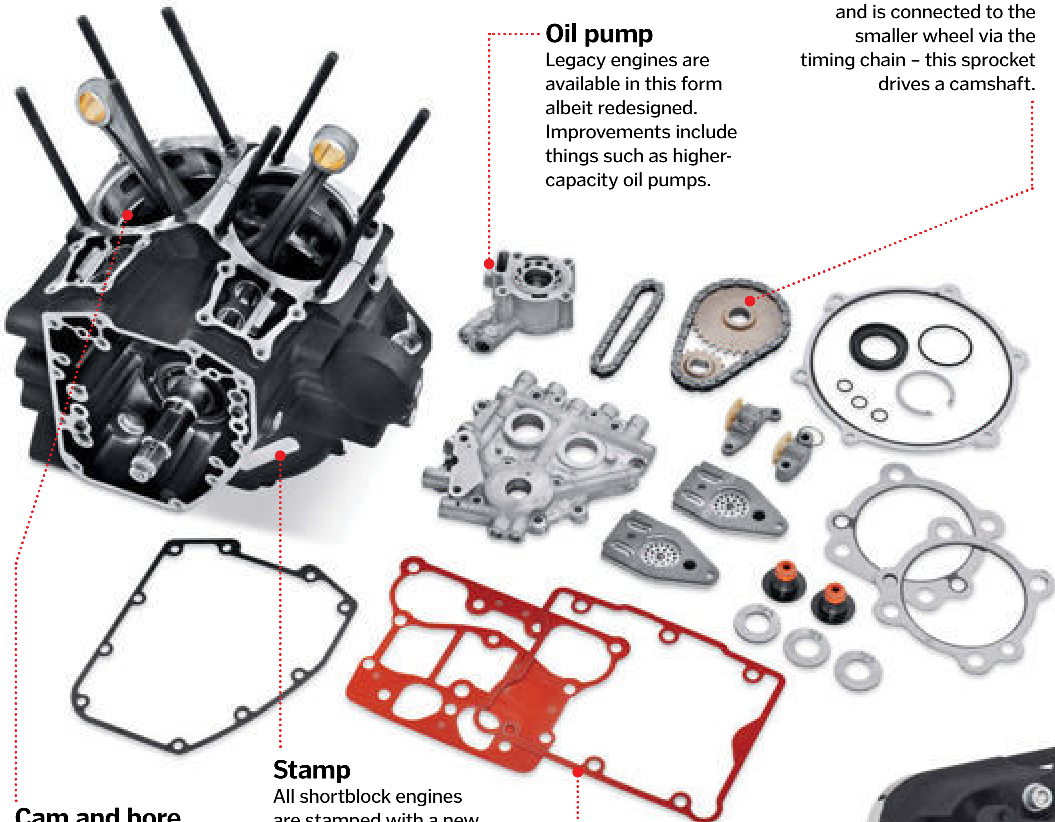
In contrast, the Harley-Davidson Sportster range is – as its name would suggest – a smaller, lighter and more sporty alternative to the FL Touring series. They are fitted with the rubber-mounted, fuel-injected Evolution (Evo) engine, of 883cc or 1,200cc capacity; designated XL, this means there's a range of XL883 and XL1200 models. Further, the 1984-introduced Softail design has rear suspension (as opposed to 'hardtail' non-suspension bikes), but it is concealed, with the springs and dampers positioned along the axis of the bike frame. This maintains its distinctive retro look.

Not all Harley-Davidson designs are slaves to the past though. The modern VRSC range, introduced in 2001, is a very advanced design that is based around a new 60-degree V-Twin engine developed with Porsche. Dubbed the 'Revolution' motor, this is an overhead cam design, with liquid cooling for the first time on a Harley, and was originally launched in 1,130cc guise. It could rev to an unheard-of (for H-D) 9,000 rpm and produced 86 kilowatts (115 horsepower) at 8,250 rpm.

It was upgraded to 1,250cc in 2005, producing 92 kilowatts (123 horsepower), and there's now a long-stroke 1,300cc version, using a revised crankshaft, that produces 123 kilowatts (165 horsepower). These 21st-century Harley-Davidsons also contain other never-before-seen features such as hydroformed frame members and a fuel tank under the rider's seat.

Engine kits explained

Harley-Davidson is well known for its DIY engines; HIW explores some of the major elements found in a shortblock engine kit



Timing chain drive
The large drive wheel is driven by the crankshaft and is connected to the smaller wheel via the timing chain – this sprocket drives a camshaft.

Oil pump
Legacy engines are available in this form albeit redesigned. Improvements include things such as higher-capacity oil pumps.

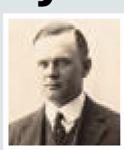
Cam and bore
Shortblock engine buyers can choose specific cam set and bore size for the performance they want.

Stamp
All shortblock engines are stamped with a new vehicle identification number (VIN) and also include a Manufacturer's Certificate of Origin (MCO).

Gaskets and seals
All the necessary gaskets and seals are included in the kits, along with the hardware required to install the engine into a bike.

Who founded Harley-Davidson?

William S Harley
William S Harley was the catalyst for the creation of Harley-Davidson. He designed a small 116cc engine in 1901 that he intended would be fitted to a regular pushbike. When this was found to be not powerful enough, he designed a larger 405cc motor: the Harley legend was born. He remained the firm's chief engineer until his death in 1943, and received a degree in mechanical engineering in 1907.



Arthur Davidson
A close friend of William S Harley, Arthur Davidson was the businessman in the partnership and his family helped get the company off the ground. It was Arthur Davidson that diverted Harley-Davidson's production to the US war effort – to be later rewarded with strong sales from loyal returning troops. Both he and Harley were inducted in the US Labor Hall of Fame for dedication to their staff.

1952
K model
Harley introduces the side-valve K model. This smaller, sportier machine will go on to become the Sportster still around today.

1965
Glide
The Electra-Glide replaces the Duo-Glide. It has the modern convenience of an electric starter.

1975
Knievel at Wembley
Daredevil Evel Knievel was sponsored by Harley-Davidson. Riding an XR-750 he jumps over 13 buses in front of 90,000 people at Wembley but then crashes.

1981
New management
Harley is bought out and revived by an investment group including Willie Davidson, grandson of co-founder William A Davidson.

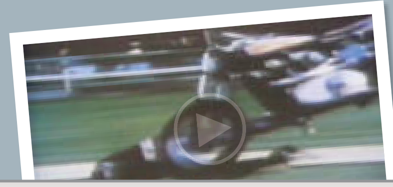
1984
Softail
H-D introduces the FXST Softail, which uses a new method of hiding the rear shock absorbers. It will go on to become one of the highest-selling models.

AMAZING VIDEO!

SCAN THE QR CODE FOR A QUICK LINK

Watch a montage of some cool Knievel stunts!

www.howitworksdaily.com



DID YOU KNOW? *Harley-Davidson motorcycles are nicknamed 'hogs' because the early race team's lucky mascot was a pig*

Twin Cam 103 anatomy

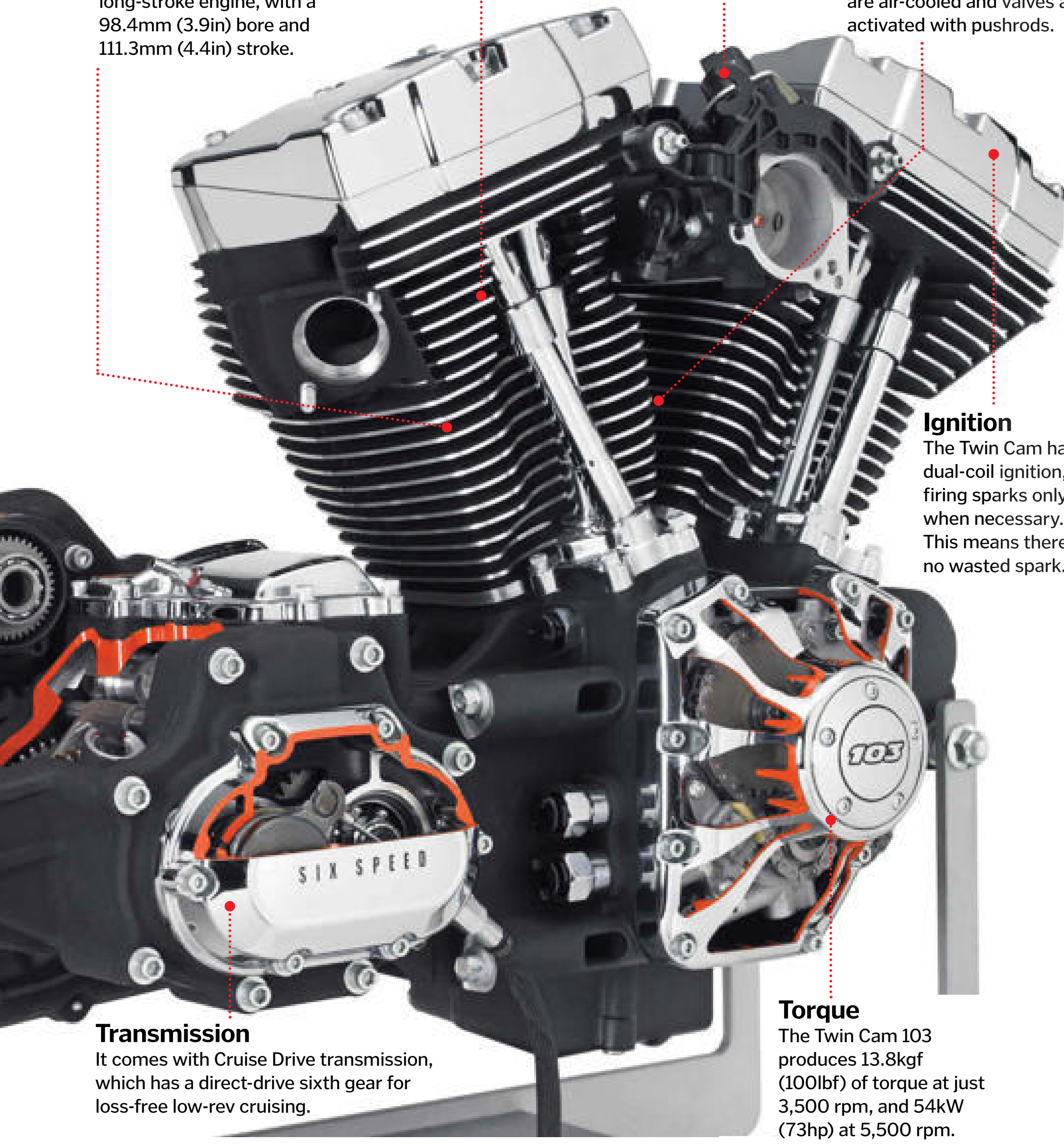
The Harley-Davidson Twin Cam 103 engine boasts some seriously advanced tech

Capacity
The 103ci capacity equals 1,690cc in European dimensions. It is a long-stroke engine, with a 98.4mm (3.9in) bore and 111.3mm (4.4in) stroke.

Piston
The pistons in the 103 are lightweight: this means that the twin-cylinder motor can deliver its performance smoothly despite its considerable output.

Injection
An electronic sequential port fuel injection is equipped to the Twin Cam. This gives sharper throttle response at high speeds and much more smoothness at lower speeds.

Cooling
The engine sticks closely to its roots in some ways: it has a 45-degree 'V', the cylinders are air-cooled and valves are activated with pushrods.



Ignition
The Twin Cam has dual-coil ignition, firing sparks only when necessary. This means there is no wasted spark.

Transmission
It comes with Cruise Drive transmission, which has a direct-drive sixth gear for loss-free low-rev cruising.

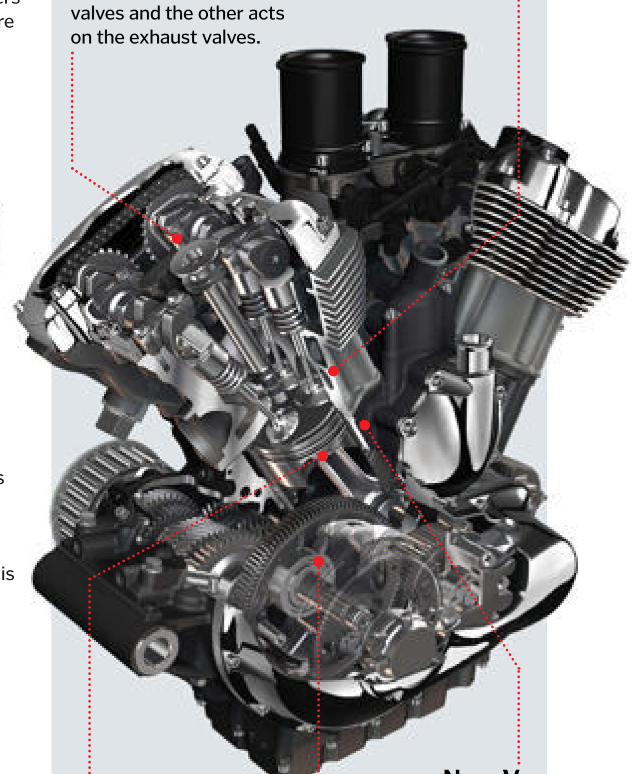
Torque
The Twin Cam 103 produces 13.8kgf (100lbf) of torque at just 3,500 rpm, and 54kW (73hp) at 5,500 rpm.

Inside the Revolution

Designed for the VRSC cruiser range, this engine is a break away from the H-D norm

DOHC
The Revolution engine has a double overhead cam design, with four valves per cylinder. One cam acts on the inlet valves and the other acts on the exhaust valves.

Water cooling
Unlike other Harley engines, the Revolution motor is water cooled.



Short stroke, high revs
The Revolution has a shorter stroke than most H-D engines – the piston travels up and down by 72mm (2.8in), whereas the bore size of the cylinder is 100mm (3.9in). This means it can rev higher than other Harley bikes.

New V
The 'V' angle of the Revolution motor is 60 degrees, unlike the traditional 45-degree angle of the classic Harley engine.

Perfect balance
The Revolution engine is counterbalanced for smoothness: it uses a single forged steel counterweighted crank which is driven at engine speed.

1994
Superbike
80 years after Harley-Davidson began competing, it enters the high-level sport of superbike racing.

1997
Milwaukee
A new product development centre is opened next to the Capitol Drive plant in Milwaukee, WI (right). It is dedicated to William G Davidson.

1998
Global success
To meet demand in growing nations, Harley-Davidson opens its first overseas production plant in Brazil.

2000
Renaissance
The Softail gets a counterbalanced version of the Twin Cam engine, dubbed 88B. It even has fuel injection.

"For jettison-based systems, small charges around the canopy's base are set off in order to release it"

Ejection seats explained

How are pilots safely launched out of planes in times of danger?

Ejection seats are a type of in-cockpit motorised chair that, in an emergency situation, can rapidly propel themselves – along with their occupant – out of an aircraft.

The propulsion force is delivered by either the detonation of an explosive charge located under the seat or by rocket motor, with the ejection out of the cockpit occurring in two key stages.

The first stage involves the canopy/hatch of the cockpit being jettisoned or destroyed, clearing the area above the pilot's head. For jettison-based systems, small charges around the canopy's base are set off in order to release it from the fuselage, while destruction-based examples have an explosive cord embedded within the acrylic plastic of the canopy that shatters it milliseconds prior to the seat being launched.

The second stage, which occurs less than a second after the removal of the canopy, entails the seat itself being hurled upwards through the now open roof. Here a rocket motor or charge propels the chair up to a set altitude and then another small charge is blown to deploy a large, built-in parachute.

Although this is the most common ejection system, others also exist. Alternative varieties include those where the entire cockpit is ejected, others that fire the seat directly through the physical canopy to shatter it, and drag extraction systems, which utilise the airflow past the aeroplane to move the pilot out of the cockpit on a guide rail.

Captain Christopher Stricklin escapes from a US Air Force Thunderbirds F-16 less than a second before it impacts the ground. Stricklin was ejected by an Advanced Concept Ejection Seat (ACES) II

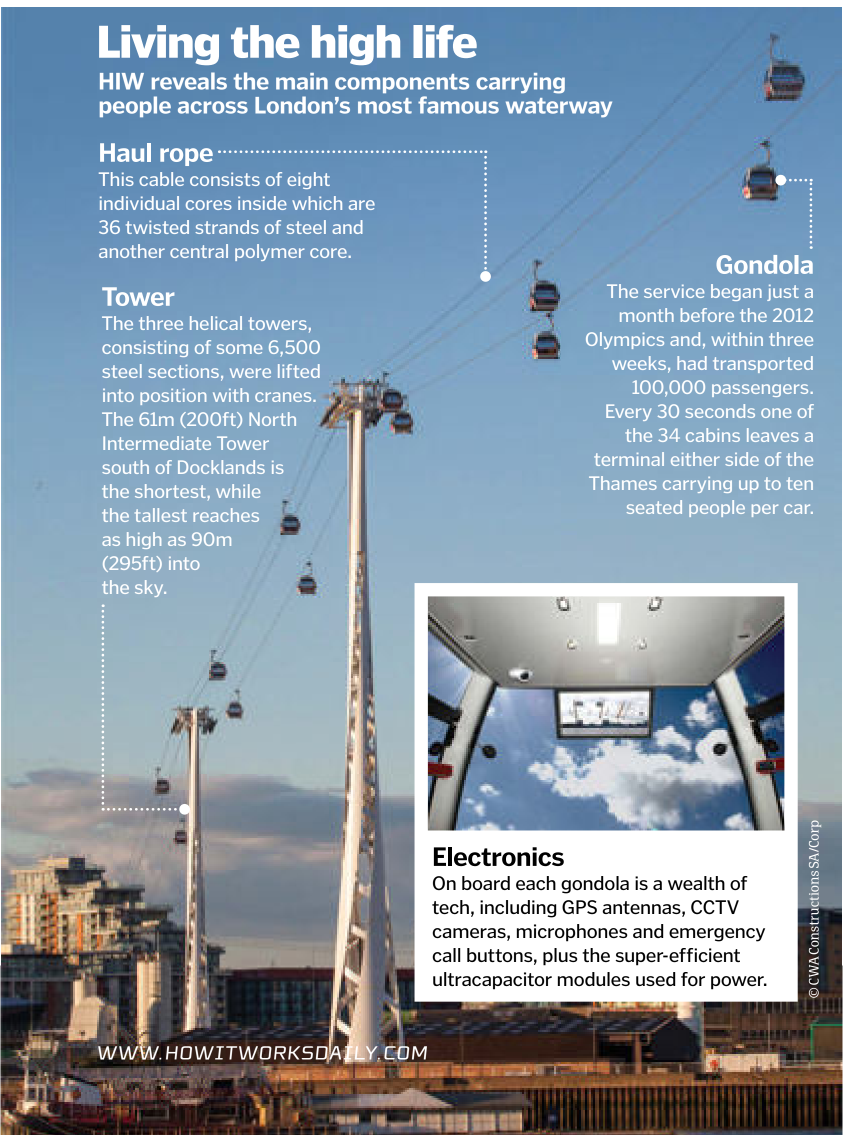
London's first cable car

See how the Emirates Air Line transports passengers 90m above the River Thames

Spanning 1.1 kilometres (0.7 miles) across the River Thames between Greenwich Peninsula and Royal Docks in London is the UK's first-ever urban cable car.

Detachable grips are connected to a continuously moving twisted steel cable, or haul rope. This haul rope is one long, 50-millimetre (two-inch)-thick cable that loops across the river and back again around two bullwheels inside the terminals on either side. It rotates at a line speed of up to six metres (19 feet) per second and slows down to 'creep speed' in the terminals for boarding and disembarking. The grips grab or release to slow down or speed up the cars.

The main terminal contains the drive bullwheel which, powered by electric motors, turns to propel the cable. This is also the location of the various braking mechanisms, including the emergency brake behind the bullwheel, the service brake and the anti-rollback brake.




Wilbur (right) and Orville attend the Belmont Park Aviation Meet, NY, in 1910

The Wright brothers

These siblings played a pivotal role in the evolution of powered flight and radically altered the path of aviation history

Wilbur and Orville Wright are two of history's most famous aviation pioneers who, through a series of experiments in the late-19th and early-20th centuries, created the first controllable, powered, heavier-than-air aircraft. Named the Wright Flyer, the plane was the culmination of over a decade's worth of research and trials that saw the brothers progress from custom-built kites, through to gliders and finally on to engine-powered aeroplanes. Together these talented siblings are generally credited with launching the age of powered flight.

Wilbur and Orville Wright were the sons of Milton Wright, an ordained minister of the Church of the United Brethren in Christ, and Susan Catherine Koerner Wright. The family lived in various locations including Richmond, IN; Cedar Rapids, IA; and Dayton, OH – the latter for the majority of the brothers' lives. Orville later explained that his father had encouraged both of them from an early age "to pursue intellectual interests and to investigate whatever aroused curiosity."

This encouragement led Orville and Wilbur into a diverse range of interests and expertise including printing, bicycles – which the pair sold and repaired for several years – and the construction of various machines from wood and metal. Both engineers and inventors, the brothers became well known for their academic and practical application of modern engineering, with Wilbur especially spending much time in his father's and public libraries.

One of their heroes was German gliding pioneer Otto Lilienthal, who up until his death in 1896 had built and flown a series of aircraft to varying degrees of success. His death, however – which was the result of a glider crash – oddly spurred the brothers' interest in flight, with them writing to the Smithsonian Institution for suggestions on other aeronautical manuscripts. One of the museum's recommendations was the engineer Octave Chanute, a leading authority on aviation and civil engineering at the time.

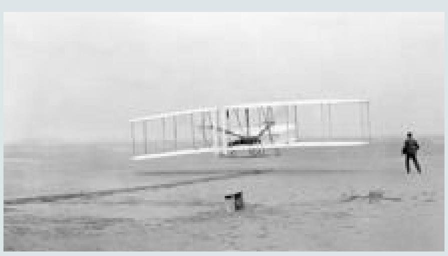
With Chanute's help the brothers began conducting a number of aeronautical experiments. Crucial to their approach was the focus on control of the aircraft, advancing previous designs that could only fly in a straight line by introducing a helical twist across the wings in either direction. The brothers tested this configuration in 1899 and, after discovering that it allowed the acute control of a kite, began working on a full-scale model: the first Wright Glider. It was tested in October 1900 at Kitty Hawk, NC, where although lifting off the ground, it produced disappointing results.

The Wright brothers refined their glider and tested it in 1901, then again in October 1902 after spending the summer undertaking a vast series of tests into more efficient wing designs. This

The big idea

Prior to the Wright brothers' successful flight (pictured below), many other scientists and engineers had dreamed about and, to varying degrees of failure, attempted to build machines that could not only defy gravity, but do so in a controlled manner. Their failures left the idea of a non-dirigible method of flight as mere fancy, with materials, aerodynamics and energy supplies all seeming insurmountable obstacles.

What is testament to the Wright brothers' expertise is that they addressed each one of these issues with their aircraft in turn, solving in years what countless minds had failed to address in centuries. Examples include the testing of hundreds of wing designs in a custom-built wind tunnel to determine which shape best granted lift, designing and building their own four-cylinder internal combustion engine that was adapted for air travel and recognising that propeller blades could be understood as rotary wings.



Up, up & away

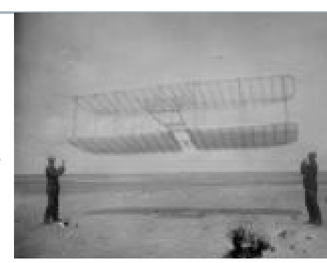
The main milestones that led to the Wright Flyer taking off...

1867 Wilbur is born, with Orville arriving four years later.

1869 The Wright family move to Dayton, OH, due to the father's work commitments.

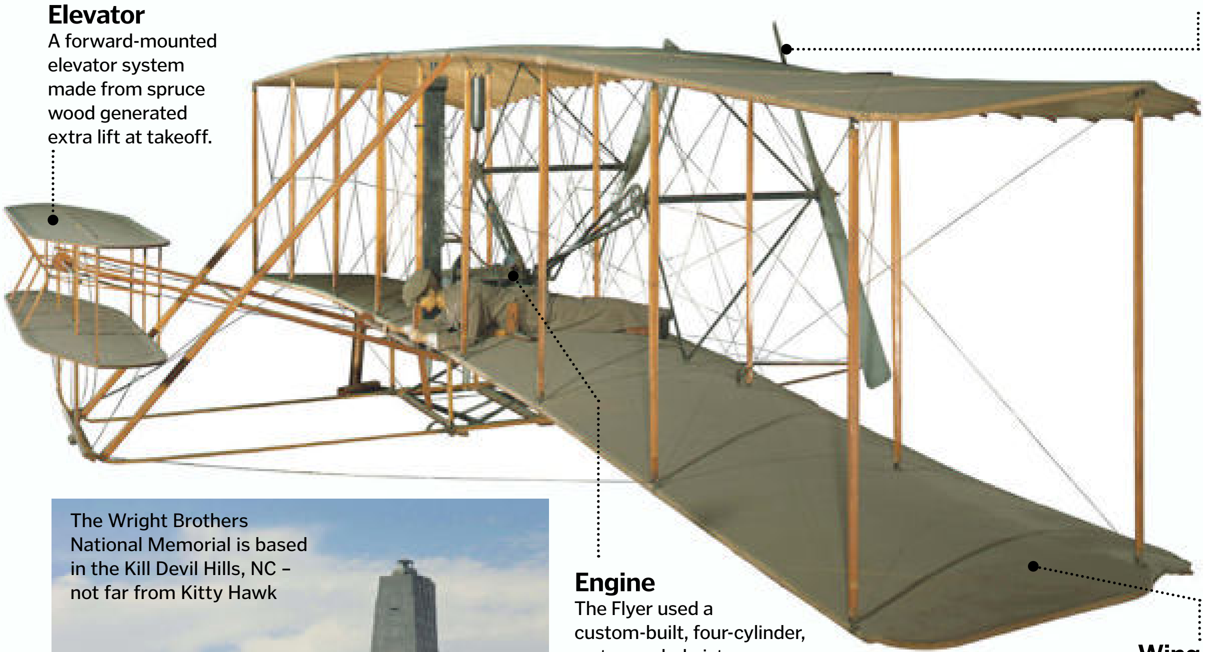
1892 Both brothers team up to open a bicycle repair shop. They begin building bikes a few years later.

1900 Years of research lead to the brothers testing the Wright Glider (right), an unpowered biplane with a forward elevator for pitch control.



The Wright Flyer in focus

Take a closer look at the pinnacle of the Wright brothers' aviation careers




The Wright Brothers National Memorial is based in the Kill Devil Hills, NC – not far from Kitty Hawk

third model was the breakthrough, with the glider performing exactly as predicted. The pair – who each piloted the glider in turn – racked up almost 1,000 flights between them over a two-month period, covering distances at Kitty Hawk of up to 190 metres (622 feet).

Realising they had cracked both the aerodynamic and control issues that all of their predecessors had struggled with, the two brothers turned their attention to a powerplant for the glider. In 1903 they built their own four-cylinder internal combustion engine and returned to Kitty Hawk to trial it. Unfortunately the first attempt ended in the engine stalling during takeoff and the front of the plane getting damaged, but after a couple of repairs, the second flight ended in resounding success.

Lifting off at 10.35am on 17 December 1903, the Wright Flyer flew 36 metres (120 feet), then 53 metres (175 feet), followed by 60 metres (200 feet) and finally 259.7 metres (852 feet). This series of flights heralded a new era of aviation and propelled the Wright brothers and their aeroplane to worldwide fame.

In their footsteps…

Octave Chanute

While not a protégé of the Wright brothers, Octave Chanute was a key collaborator. A French-born American railway engineer and aviation pioneer, Chanute worked extensively with the brothers and even produced his own gliders, kites and model aircraft. He also wrote a celebrated book on early aircraft: *Progress In Flying Machines*.

Augustus Herring

This American aviator followed in the Wrights' and Chanute's footsteps by actually flying a compressed air engine biplane glider. In addition, in 1909 Herring set up an aviation company and, despite suffering from a series of strokes, went on to work with the US Army in the design of aircraft used throughout World War I.

Top 5 facts: Wright bros

1 No college
Wilbur and Orville were the only members of the Wright family who didn't attend college. Orville spent the years learning the printing trade, while Wilbur helped at the local church.

2 Lifelong bachelors
Neither of the Wright brothers married throughout their lives. Wilbur is recorded as once saying that he "did not have time for both a wife and an airplane."

3 Child's play
In their later lives, the Wright brothers attributed their fascination with flying machines to a small toy helicopter which their father had brought home one day from his travels.

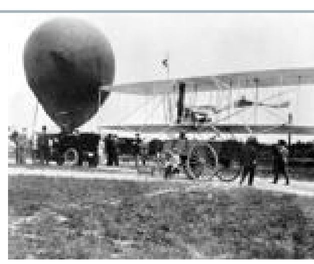
4 Luminaries
Both of the brothers extensively catalogued their aviation experiments, leading to Wilbur Wright delivering a talk at the prestigious Western Society of Engineers in Chicago in 1901. The speech was entitled 'Some Aeronautical Experiments'.

5 Hobby to business
In 1909 the Wright Company was incorporated with Wilbur as president and Orville as one of two vice-presidents. The company's factory was based in Dayton and their flying field at the nearby Huffman Prairie.

"Both engineers and inventors, the brothers became well known for their academic and practical application of modern engineering"

1903
The brothers successfully fly the Wright Flyer in sustained flight at Kitty Hawk, NC. Its fourth flight covers 259.7 metres (852 feet) in just 59 seconds.

1909
The Wright Company sells the first-ever military aircraft, the Wright Military Flyer (right), to the US Army Signal Corps.



1912
Wilbur dies of typhoid fever on 30 May at 45 years old.

1915
Orville ends his leadership of the Wright Company by selling his shares to a group of financiers.

1920
Orville joins the board of the National Advisory Committee for Aeronautics – a precursor to NASA.

1948
Orville suffers a heart attack on 27 January and dies three days later in Dayton, OH, aged 76.

Constructing space stations

How are habitable platforms like the ISS constructed many miles above Earth on the boundary of space?

Space stations are human habitats complete with a pressurised enclosure and life support, which are placed in a geostationary orbit, usually at an altitude of more than 300 kilometres (186 miles) above the surface of our planet. This high altitude puts them far above the thousands of commercial satellites that orbit around the 35-kilometre (22-mile) mark and allows for a number of observational experiments not possible on the ground.

These experiments include the study of the Earth, Sun and other astronomical objects from space beyond the barriers of clouds/pollution, for example, as well as tests under the effects of microgravity and investigations into how the human body responds to weightlessness.

Small space stations, like the Russian reconnaissance platform Salyut 5 and the US Skylab, can be fully assembled on terra firma and launch into orbit in their entirety. Bigger models, like the International Space Station (ISS) and its Russian predecessor, Mir, however, are more problematic. Their huge mass and awkward shape that includes long and relatively fragile solar panels perpendicular to the body make them impossible for any delivery system to take them into orbit whole. A typical shuttle or expendable rocket might at most be able to carry around 30,000 kilograms (66,000 pounds) into low Earth orbit (LEO) and much less into higher orbits, whereas the completed Mir space station was about 130,000 kilograms (285,000 pounds) and the ISS is

437 days

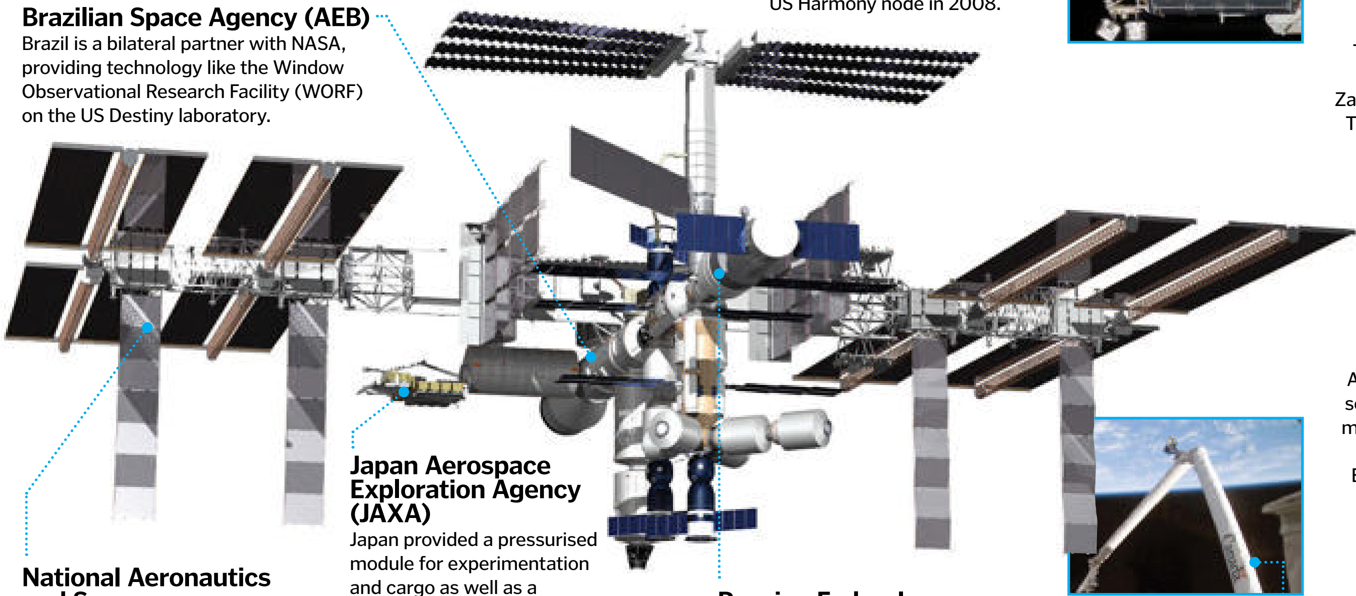
LONGEST TRIP TO SPACE

Russian cosmonaut Valeri Polyakov holds the world record for the most days consecutively in space, on his service aboard the Mir space station from 8 January 1994 to 22 March 1995.

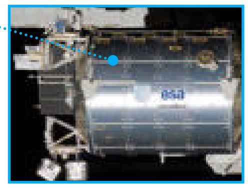
DID YOU KNOW? *The first space station was dreamt up in 1869 in a story about a 'brick moon' featured in The Atlantic Monthly*

Who helped build the ISS?

The International Space Station was constructed by many nations over the course of a decade…



European Space Agency (ESA)
The Columbus laboratory was the largest single ESA contribution, connected to the US Harmony node in 2008.



Brazilian Space Agency (AEB)
Brazil is a bilateral partner with NASA, providing technology like the Window Observational Research Facility (WORF) on the US Destiny laboratory.

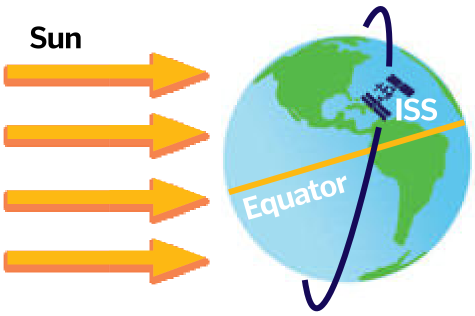
National Aeronautics and Space Administration (NASA)
The US has contributed the most modules to the ISS (seven in total) including the second module, Unity, forming the first connection of the station.

Japan Aerospace Exploration Agency (JAXA)
Japan provided a pressurised module for experimentation and cargo as well as a robotic arm, which attaches to the US Harmony node.

Russian Federal Space Agency (FKA)
Russia had the honour of creating Zarya, the first component of the ISS, launched in 1998.

Canadian Space Agency (CSA)
In conjunction with NASA, Canada's contributions to the ISS are a 17m (56ft) robotic arm (Canadarm2), a service robot (Dextre), and a mobile work platform.

How does the ISS orbit Earth?



The International Space Station orbits at an altitude of roughly 360 kilometres (220 miles) above the surface of our planet, travelling at an average speed of 28,000 kilometres (17,400 miles) per hour. On a daily basis, it completes 15.7 orbits.

The Columbia disaster

The Columbia was a NASA space shuttle that was destroyed in an accident in 2003. The flight was concerned with experiments in microgravity and, having completed its mission in space, it was re-entering Earth's atmosphere to return home when it broke apart over Texas: all seven crew members were lost. As a result, all remaining shuttles were grounded while NASA investigated the accident, which put the assembly of the partially completed International Space Station on hiatus for over two years. During this period, research was limited and a two-man crew operated a caretaker role on board the ISS.

over 400,000 kilograms (880,000 pounds) – way beyond the maximum payload of any current launch system.

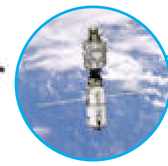
The answer to this is to launch the space station a piece at a time. As smaller modules – components with a fraction of the completed station's mass – they are constructed on the ground and sent on the back of a rocket or shuttle up to the required altitude. Assembling a space station is akin to building a boat while it's out at sea, so you have to be able to navigate and perform vital functions while building. Manning the space station with astronauts only happens at a convenient later stage with full life support. The first component therefore has to be a core module that is not only capable of propelling itself but also assisting in assembly – although this might not necessarily be its main function when the space station is completed. Once in orbit, pre-programmed commands activate vital functions like communication antennas, allowing mission control to remotely manipulate the core module. At this point it can be piloted within orbit to rendezvous and join with other modules via a bespoke docking port.

Attaching a pressurised module and getting a crew on board as soon as possible speeds up the process, as astronauts can facilitate assembly on-site. Both Mir and the ISS each took more than a decade to go from a single module to planned completion, while China's Tiangong space station is set to be finished in the early-2020s.

The ISS in pictures

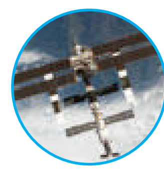
How the ISS has grown over time

1999
The ISS comprises two components: Russia's Zarya and the US's Unity. There's a single mission for supplies only.

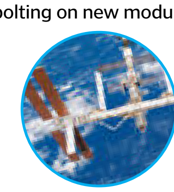


2002
A flurry of activity adds solar arrays, the Zvezda module, the Destiny lab, a robotic arm and the ESA's logistics module.

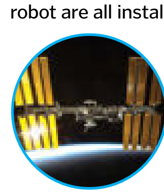
2006
After several years of maintenance after the Columbia disaster, a new solar array is connected to the electric system.



2007
Extra trusses are added for more solar arrays and communication, plus the US Harmony node for bolting on new modules.



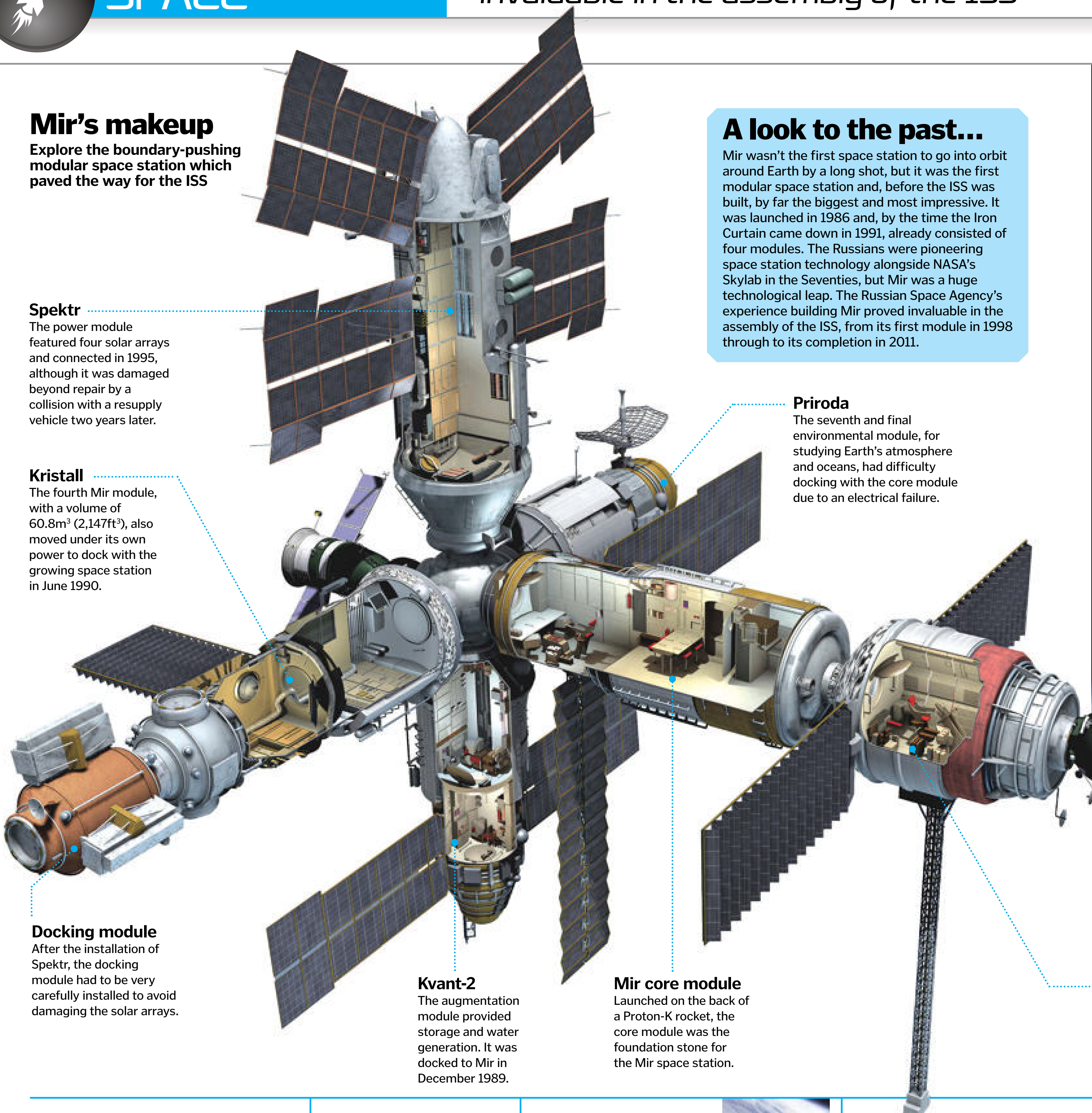
2010
The final solar array, the Japanese Experiment Module, known as Kibo, and the Canadian Dextre robot are all installed.



"The Russian Space Agency's experience building Mir proved invaluable in the assembly of the ISS"

Mir's makeup

Explore the boundary-pushing modular space station which paved the way for the ISS



Spektr
The power module featured four solar arrays and connected in 1995, although it was damaged beyond repair by a collision with a resupply vehicle two years later.

Kristall
The fourth Mir module, with a volume of 60.8m³ (2,147ft³), also moved under its own power to dock with the growing space station in June 1990.

Docking module
After the installation of Spektr, the docking module had to be very carefully installed to avoid damaging the solar arrays.

Kvant-2
The augmentation module provided storage and water generation. It was docked to Mir in December 1989.

Mir core module
Launched on the back of a Proton-K rocket, the core module was the foundation stone for the Mir space station.

Priroda
The seventh and final environmental module, for studying Earth's atmosphere and oceans, had difficulty docking with the core module due to an electrical failure.

A look to the past...

Mir wasn't the first space station to go into orbit around Earth by a long shot, but it was the first modular space station and, before the ISS was built, by far the biggest and most impressive. It was launched in 1986 and, by the time the Iron Curtain came down in 1991, already consisted of four modules. The Russians were pioneering space station technology alongside NASA's Skylab in the Seventies, but Mir was a huge technological leap. The Russian Space Agency's experience building Mir proved invaluable in the assembly of the ISS, from its first module in 1998 through to its completion in 2011.

Space station history

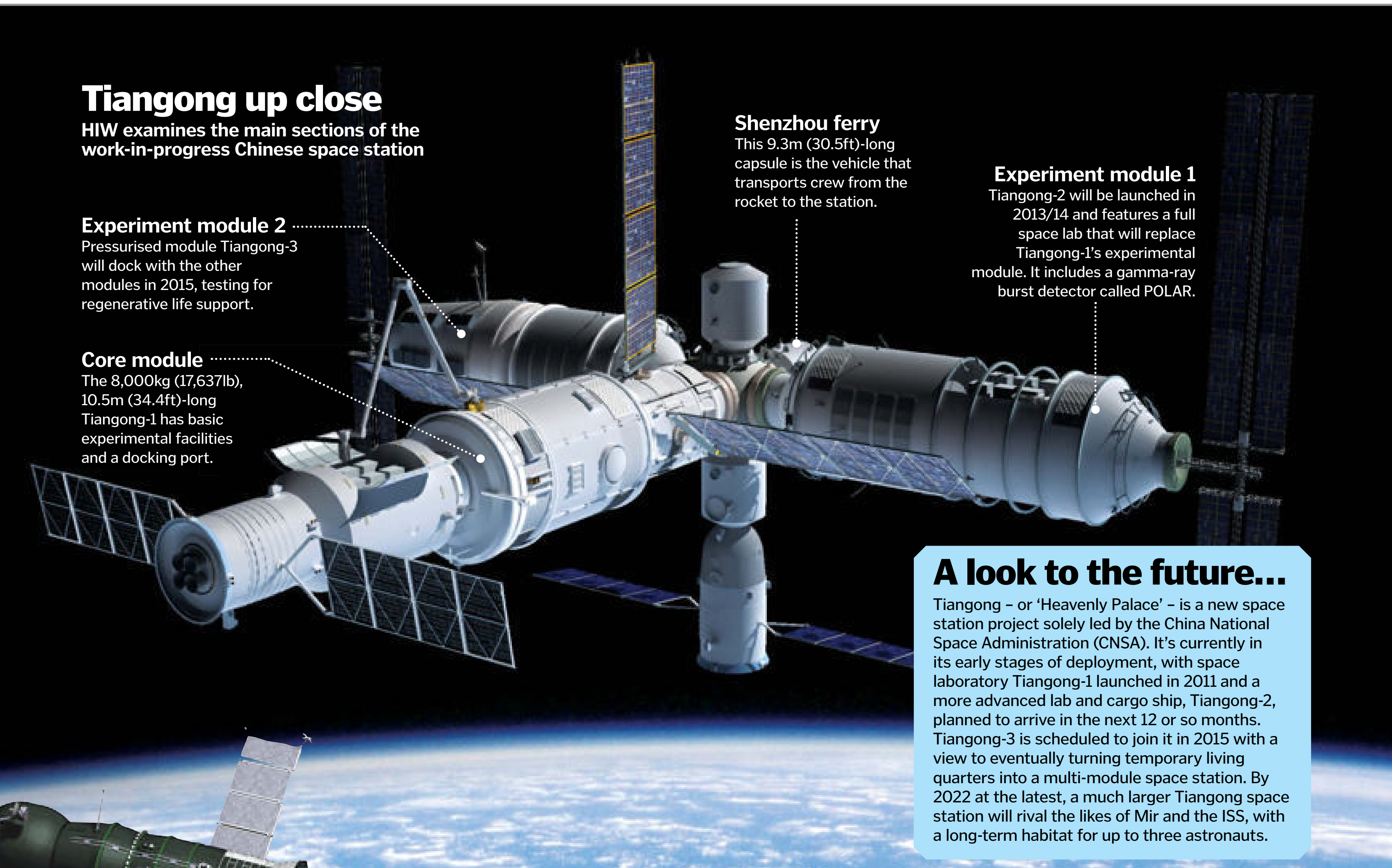
We pick some of the milestones in the evolution of these orbital stations over the last 40 years

Salyut 1
19 April 1971
The Russians set an astronomic record by building and launching the world's first space station. Salyut means 'salute', honouring the first man to enter space, Yuri Gagarin, ten years beforehand.

Skylab
14 May 1973
NASA's first space station (right) comes two years after Salyut 1. Launched on a Saturn V, it provides a more comfortable living space for its crew and their important experiments.

Salyut 6
29 September 1977
The first of the Soviet second-gen space stations is one of Russia's most successful. It studies the effects of spaceflight on the body and also plays host to many foreign astronauts.

DID YOU KNOW? *Despite Salyut 1 being the first space station, a faulty pressure valve tragically killed the crew on re-entry*



Tiangong up close

HIW examines the main sections of the work-in-progress Chinese space station

Experiment module 2
Pressurised module Tiangong-3 will dock with the other modules in 2015, testing for regenerative life support.

Core module
The 8,000kg (17,637lb), 10.5m (34.4ft)-long Tiangong-1 has basic experimental facilities and a docking port.

Shenzhou ferry
This 9.3m (30.5ft)-long capsule is the vehicle that transports crew from the rocket to the station.

Experiment module 1
Tiangong-2 will be launched in 2013/14 and features a full space lab that will replace Tiangong-1's experimental module. It includes a gamma-ray burst detector called POLAR.

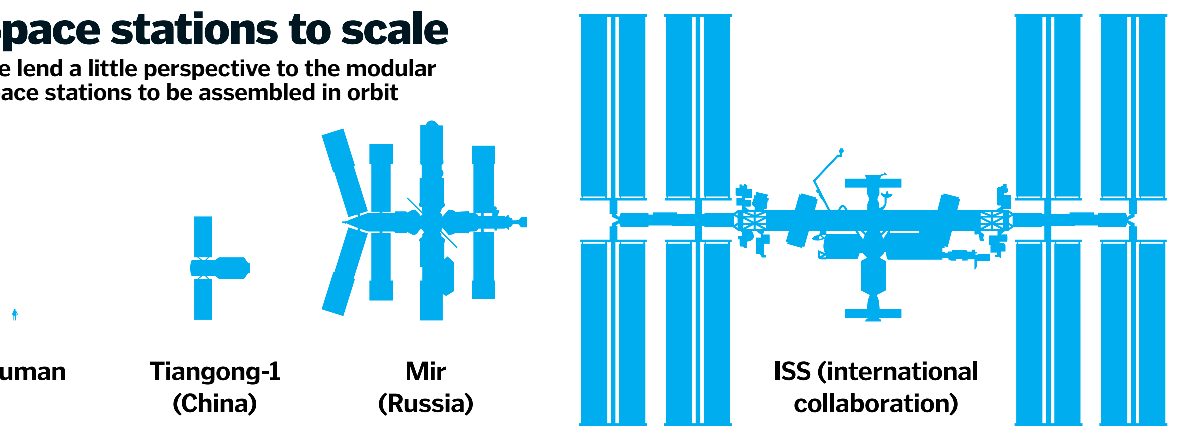
A look to the future...

Tiangong – or 'Heavenly Palace' – is a new space station project solely led by the China National Space Administration (CNSA). It's currently in its early stages of deployment, with space laboratory Tiangong-1 launched in 2011 and a more advanced lab and cargo ship, Tiangong-2, planned to arrive in the next 12 or so months. Tiangong-3 is scheduled to join it in 2015 with a view to eventually turning temporary living quarters into a multi-module space station. By 2022 at the latest, a much larger Tiangong space station will rival the likes of Mir and the ISS, with a long-term habitat for up to three astronauts.

Kvant-1
Mir's astrophysics module had no engines to propel it and had to be towed on to the core module.

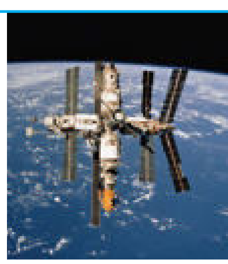
Space stations to scale

We lend a little perspective to the modular space stations to be assembled in orbit



Mir

20 February 1986
Russia launches the first modular space station (right), which orbits at 296km (184mi). Mir suffers a series of malfunctions prior to its de-orbit, having flown three times longer than planned.



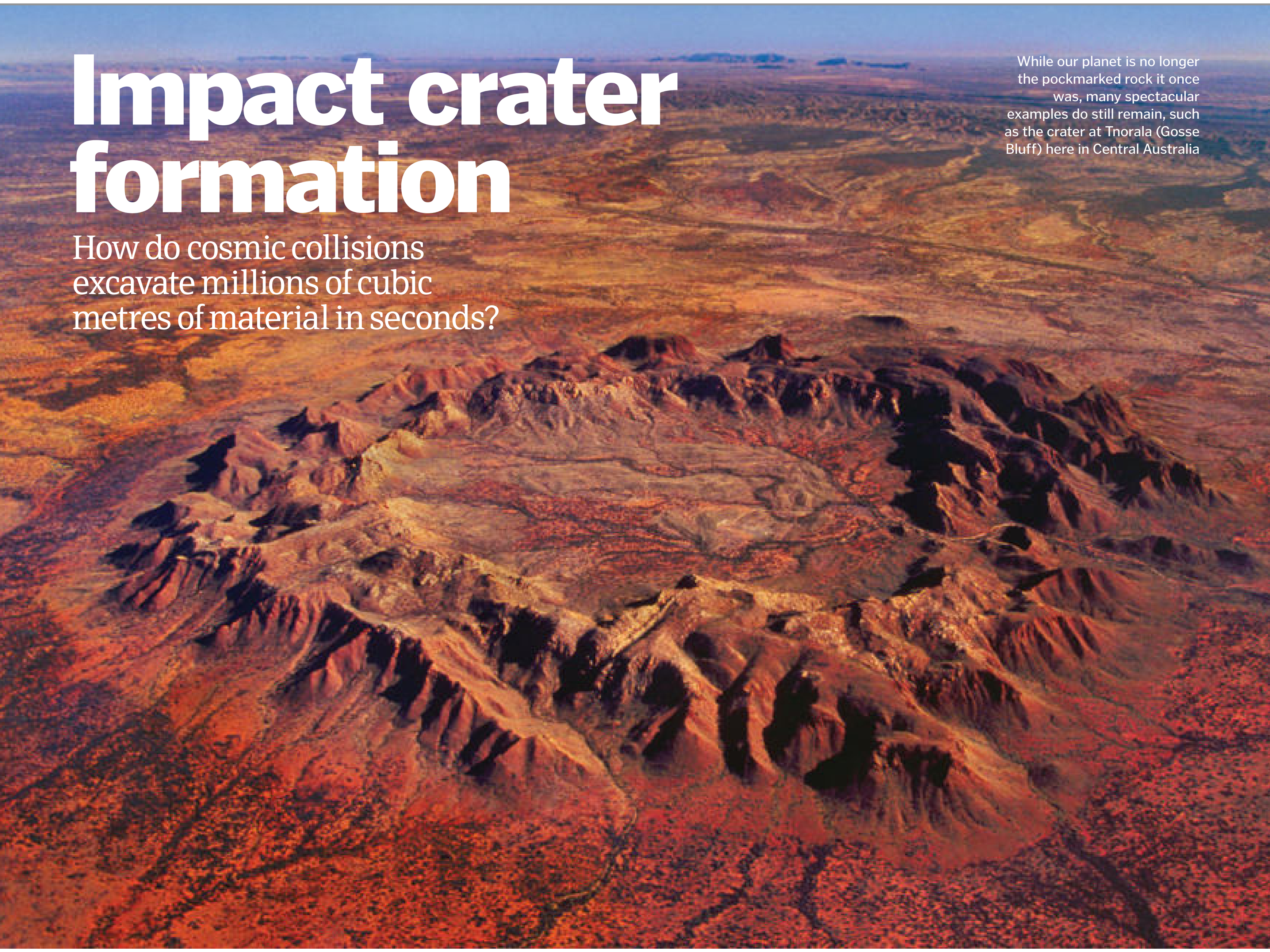
ISS

20 November 1998
The ISS (right) has been manned for over 12 years now, with crew changeovers at regular intervals. It can clearly be seen moving across the sky as a bright point just before sunrise or after sunset.

Tiangong

29 September 2011
Modules of Tiangong, China's independent project, are currently being positioned in orbit with Tiangong-2 due to be installed by 2014. The station is set to be complete by 2020.

"A ten-kilometre-wide projectile can produce a crater more than ten times that size"



Impact crater formation

How do cosmic collisions excavate millions of cubic metres of material in seconds?

While our planet is no longer the pockmarked rock it once was, many spectacular examples do still remain, such as the crater at Tnorala (Gosse Bluff) here in Central Australia

It's no surprise that the four 'rocky' planets of the Solar System – Mercury, Venus, Earth and Mars – feature their fair share of impact craters. Over the last 4.6 billion years countless natural space objects left over from the formation of the Solar System have hurtled through the galaxy and smashed into these planets and their moons.

While the dense gas of our atmosphere protects us from small impacts, larger comets, asteroids and meteoroids have broken through and crashed into Earth in the past. A space rock's typical velocity is between 40 and 70 kilometres (25 and 45 miles) per second. The air ahead of the speeding projectile is therefore suddenly compressed, and when gas is compressed the temperature rises. Indeed, when the leading edge of the object encounters air molecules at these speeds, temperatures as hot as 1,650 degrees Celsius (3,000 degrees Fahrenheit) are generated. The violent collision of atoms causes the surface of the projectile to become incandescent. When a glowing meteoroid shoots through the atmosphere it becomes known as a meteor (or 'shooting star').

While the smallest meteors boil up and melt in our planet's atmosphere, larger ones can break through and crash into the surface as meteorites. Much larger projectiles, however, will hurtle straight through the atmosphere and smash hard and fast into the ground creating huge impact craters. A ten-kilometre (six-mile)-wide projectile can produce a crater more than ten times that size.

When an impact occurs, the projectile's kinetic energy is instantly transferred to the target's surface in other forms, including heat and sound. Large meteorites travel many times faster than the speed of sound and, when they strike the ground, energy is released over a small area in a very short space of time.

The heat energy generated usually vaporises the meteorite itself. The impact, meanwhile, excavates the crater, forcing surface material (ejecta) up into the air. The initial seismic shockwave travelling out from the collision site is closely followed by a secondary 'release' wave generated by the reflection of the first wave. A central mound then often forms in the floor of the crater when the downward pressure of the impact rebounds back up.

HEAD 2 HEAD

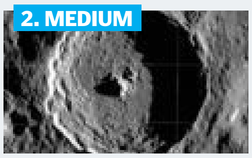
CRATER TYPES

1. SMALL

Simple

Relatively small objects create cone or bowl-shaped 'simple' craters usually 20 or so times bigger than the meteorite, eg the Barringer Crater in Arizona, USA.

2. MEDIUM



Complex

Larger meteorites form 'complex' craters with flat floors and collapsed sides. After the initial impact, the ground bounces back to create a central mound.

3. LARGE

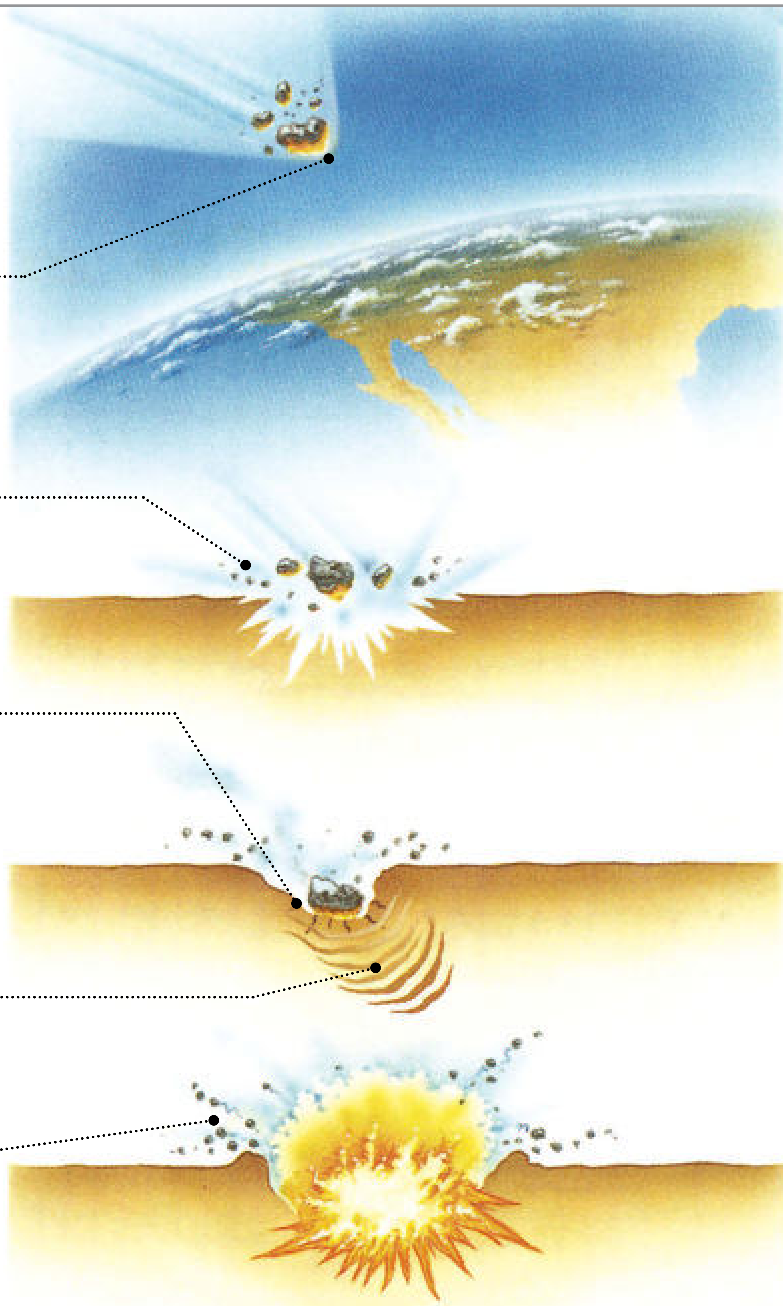
Impact basins

The largest meteorites create impact basins with rings around the edge. Valhalla on Jupiter's moon Callisto is the biggest of these in the Solar System.

DID YOU KNOW? *Lunar and Martian meteorites are very valuable things – in fact, they cost more than gold*

Making an impression

See step-by-step how an impact crater is formed



Entry

The hot, glowing leading edge of a projectile with a diameter of 10km (6.2mi) burns through Earth's dense atmosphere.

Explosion

As the impactor strikes the surface of the planet or moon the front edge collapses while the rear continues forward. This causes a huge explosion.

Crater

A depression much larger than the actual projectile is formed when the impact displaces surface rocks, throwing them into the atmosphere and leaving a crater with a diameter of some 100km (62mi).

Shockwaves

Shockwaves travel through both the surface of the celestial body and the meteorite before dissipating.

Vaporised

While the impact usually vaporises the projectile itself, some melted or shattered meteorite fragments are left behind.

Did a mega impact kill off the dinosaurs?

It's believed that 65.5 million years ago Earth may have been struck by a number of massive asteroids whose impacts triggered the K-T (Cretaceous–Tertiary) global extinction event thought to have wiped out around 80 per cent of Earth's animal and plant species – most notably all the non-avian dinosaurs.

As well as the immediate annihilation caused by such an asteroid impact, other fatal consequences include wildfires ignited by the burning rock, kilometre-high mega-tsunamis triggered by the shockwaves, global clouds of dust and other ejecta capable of blocking out the Sun for a decade, as well as endless other knock-on effects from the strike.

Evidence that supports the asteroid theory includes the discovery of the 180-kilometre (111-mile)-wide Chicxulub Crater in Mexico's Yucatán Peninsula. What's amazing about Chicxulub is that it's not actually visible above ground; its structure lies almost a kilometre (0.6 miles) below today's surface. The crater was only discovered in the Seventies by people prospecting for oil.

Amazing craters

Linné Crater

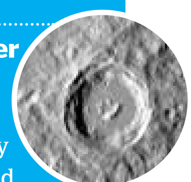
Location: Moon

The Moon is a great place to study impact craters as there is no weather to erode them, leaving them preserved for millions of years. The Linné Crater is also relatively young and this means it has not been damaged by further impacts.

Spider Crater

Location: Earth

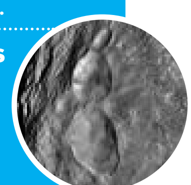
Before life emerged, Earth's surface was as cratered as the Moon's. Today, however, our atmosphere, liquid water and tectonic activity have all eroded and reshaped the surface. For hundreds of millions of years the Spider Crater in Western Australia has been worn away except for the harder leg-like layers made of sandstone.



Happy Little Crater

Location: Mercury

Smiling away on Mercury is the Happy Little Crater, so-called because the central mounds of this complex feature uncannily resemble a smiley face. It has a diameter of 37 kilometres (23 miles).



Snowman Craters

Location: Vesta

One of the biggest asteroids in the Asteroid Belt, Vesta carries many impact formations including three craters – Marcia, Calpurnia and Minucia – which together look a bit like a snowman. For some reason, Vesta's northern half is more heavily cratered than the southern half.

1.079bn km/h

SPEEDY SPACE JETS

Relativistic jets travel at nearly the speed of light (99.995 per cent) and are some of the fastest-known phenomena in the cosmos.

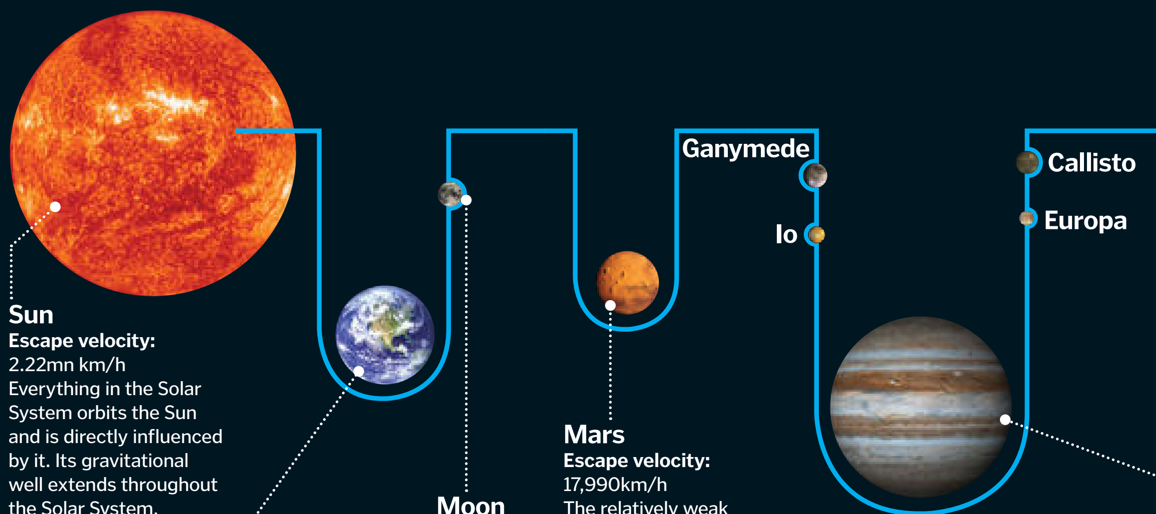
DID YOU KNOW? *Gamma-ray bursts (GRBs) – the brightest events in the universe – are a result of stellar jets*

Jupiter's gravity

How does this gas giant exert such a large influence on the Solar System?

Jupiter is the largest and most massive planet in the Solar System, so it should come as no surprise that it also has a huge effect on pretty much everything in its vicinity. Indeed gravity on this gas giant is approximately two and a half times that experienced on Earth, but what does that really mean in space terms? The accompanying illustration should help you get your head around it.

Each celestial object exerts an influence on its surroundings through what is known as its gravity well. If you are on the surface of the body, you are said to be at the bottom of its gravity well. The bigger the well the harder it is to get off the object. To escape you need to travel over a certain velocity; a few of the numbers have been crunched here...

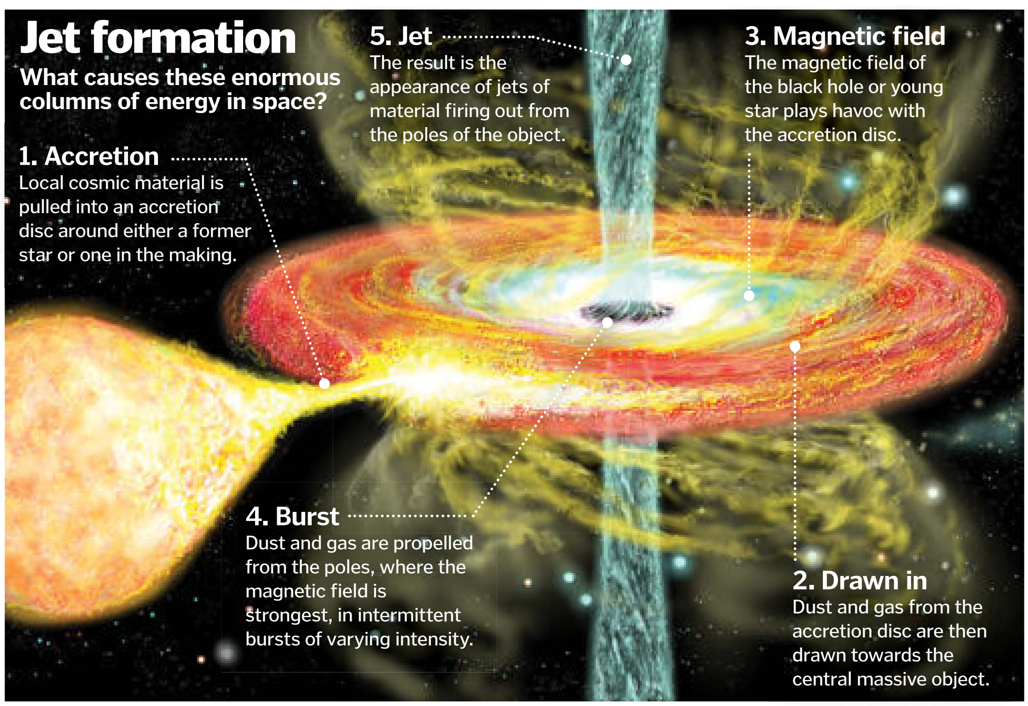


What are stellar jets made of?

Discover the origins of these huge outpourings of energy from stars and black holes

Stellar jets are huge outbursts of plasma from a young star, planetary nebula or black hole that can be trillions of kilometres long and expand at speeds anywhere from hundreds of kilometres a second to something approaching the speed of light. Jets like these are the result of a ring of dust and gas (called an accretion disc) being pulled into a dense object like a protostar or black hole and subsequently being fired out from its two poles in opposite directions. However, what exactly happens between the material being sucked from the disc into its host object and then being propelled into interstellar space is a matter of debate.

Another mystery is the longevity of the jets. Previously, it was thought that they are constantly emitted, but observations of scattered jet material suggests that they actually fire periodically like relativistic bullets, spreading debris into the interstellar medium as the star or black hole rotates.



"It's generally accepted that the Asteroid Belt is a vestige of our early Solar System"

The Asteroid Belt

Why are there millions of rocks orbiting between Mars and Jupiter?

Since the first object in what is now commonly known as the 'Asteroid Belt' was observed in 1801, over 100,000 asteroids have been found in the same region. More than 90 per cent of these have been discovered in the last decade and there are suspected millions more too small to be of note. So what are they all doing there and why aren't these bands of space rock more common?

When the dwarf planet Ceres was first spotted, quickly followed by the large asteroids Juno and Vesta, it was proposed that they were the remains of a larger planet that had succumbed to a catastrophic event such as a massive impact with another celestial body. The theory stuck for decades but today most scientists consider this origin of the Asteroid Belt an unlikely scenario. The energy required to shatter a progenitor planet even of this small size would have been enormous and, besides, the range of elements and chemicals present in the various asteroids suggest they originated from something other than a single body.

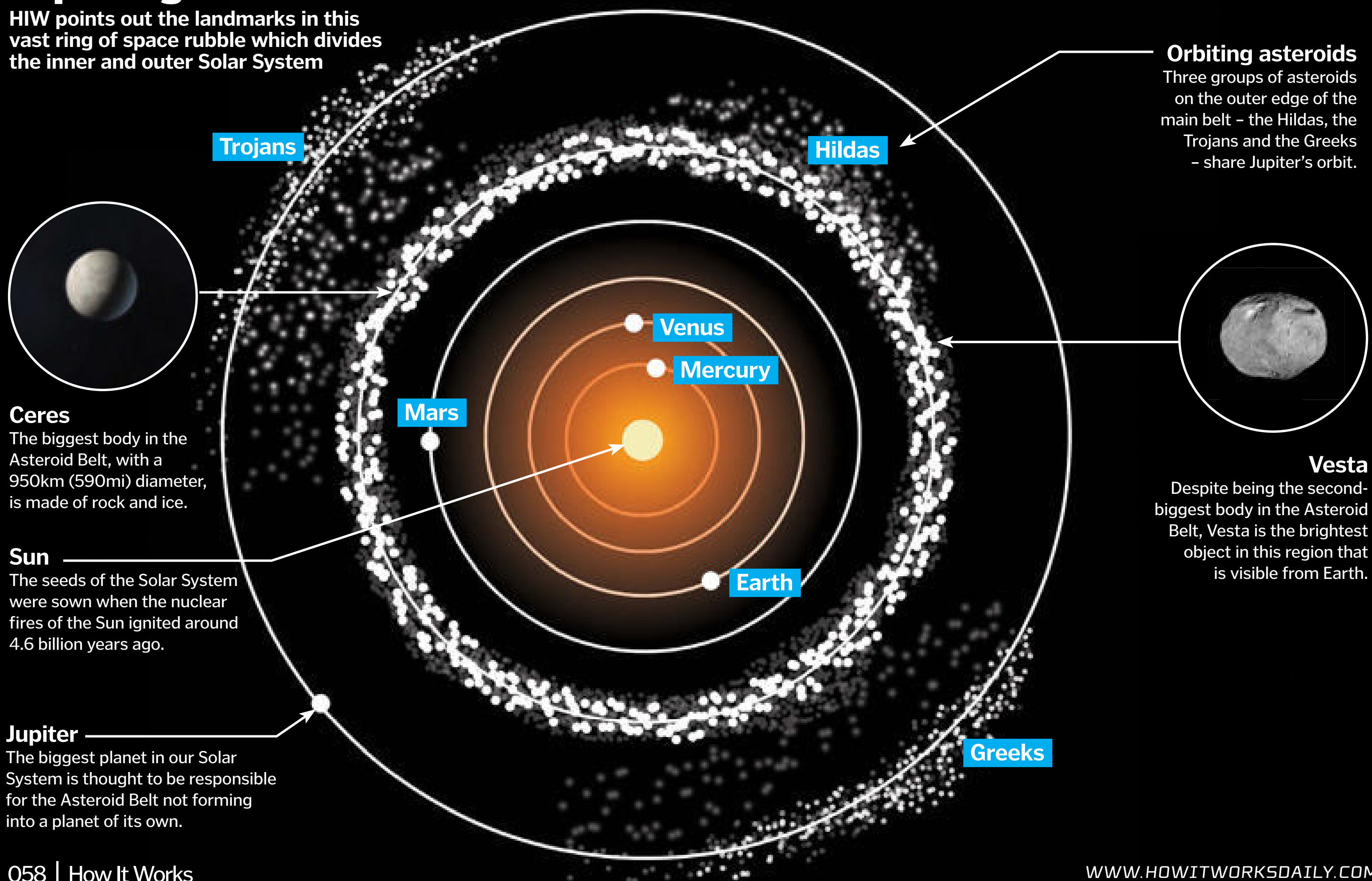
It's generally accepted that the Asteroid Belt is a vestige of our early Solar System. Though we still don't know exactly how our planetary system evolved, it's believed that a collapsing nebula created the Sun and then each planet – both rocky and gaseous – developed out of accreting particles orbiting in discs similar to today's Asteroid Belt. However, the millions of particles between Mars and Jupiter were unable to form a planet in this way because they were perturbed by the mighty influence of Jupiter's gravity. So instead they have remained as a disc of orbiting material to this day.

How was the belt discovered?

While viewing the known Solar System in 1766, German astronomer Johann Daniel Titius made a very insightful observation. He noticed a mathematical pattern in the layout of the planets: if you applied a certain regular numerical sequence to the order of the planets, it very closely approximated the orbital radii of each. The formula was substantiated when William Herschel discovered Uranus in 1781, matching its orbital radius almost exactly. There was a problem, however: by what would later be known as the Titius-Bode Law, there should have been a planet between Mars and Jupiter, but 18th-century astronomers could see nothing there. Suddenly, that conspicuously empty region of space became an observational hotspot. Titius-Bode has since been proven to be a mere coincidence, but it prompted us to point our telescopes towards a region of space much earlier than we might have otherwise.

Exploring the belt

HIW points out the landmarks in this vast ring of space rubble which divides the inner and outer Solar System



THE STATS
ASTEROID BELT

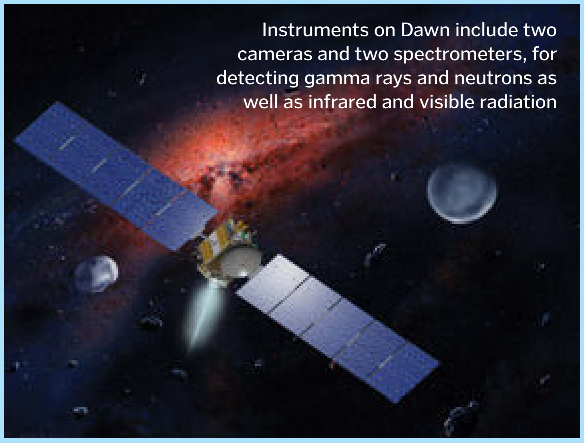
ASTEROIDS WITH DIAMETER >100KM	220
ASTEROID BELT TOTAL MASS	3.6×10^{21}kg
VESTA'S ORBIT (EARTH YEARS)	~3.6
ASTEROID BELT AGE	4.5bn yrs
CERES' DIAMETER	950km
CARBON-ROCK ASTEROIDS	75%

DID YOU KNOW? *The only dwarf planet in the inner Solar System, Ceres makes up 33 per cent of the Asteroid Belt's mass*

Dawn in the Asteroid Belt

In 2007, NASA launched the Dawn spacecraft with a mission not to visit any of the main planets in the Solar System, but the Asteroid Belt. It arrived at Vesta – one of the first objects ever observed in the region – in July 2011 and was inserted into its orbit. The main mission of Dawn is to gather data from the largest bodies in the Asteroid Belt to give scientists on Earth a clearer picture of how the Solar System formed.

Dawn left Vesta in September 2012 and is due to reach the biggest object in the Asteroid Belt – the dwarf planet Ceres – in February 2015. It's the first exploratory probe to be powered by ion propulsion, using three xenon ion thrusters, meaning it's easily capable of making multiple insertions. In contrast, standard chemical propulsion limits spacecraft like the Voyager probes to only flybys on secondary targets.


Instruments on Dawn include two cameras and two spectrometers, for detecting gamma rays and neutrons as well as infrared and visible radiation


In this computer artwork the five innermost planets are shown orbiting the Sun, with the Asteroid Belt located between Mars and Jupiter

WONDERS OF THE NILE

It is one of Earth's most astounding waterways, but how does the Nile affect its arid surroundings?

Understandably considered to be the 'father of African rivers', the River Nile is quite simply awe-inspiring. Rising from south of the equator in Uganda and winding through north-east Africa all the way to the Mediterranean Sea, it is not just Earth's longest river (though some have contested it's beaten by the Amazon), but indisputably one of the most historic and diverse.

The Nile is formed from three principal sources: the White Nile, Blue Nile and Atbara. The White Nile begins at Lake Victoria, Uganda, and is the most southerly source. The Blue Nile begins at Lake Tana, Ethiopia, and is its secondary source, flowing into the White Nile near Khartoum. Lastly the Atbara River, which begins around 50 kilometres (30 miles) north of Lake Tana, is the third and smallest source, joining the other two bigger waterways at the eponymous Sudanese city of Atbara.

Combined, these three primary sources create the River Nile, which today is naturally split into seven distinct regions ranging from the Lake Plateau of eastern Africa down to the vast Nile Delta that spans north of Cairo. These areas are home to diverse peoples and cultures, exotic flora and fauna, as well as a variety of notable physiographical features ranging from fierce rapids, through to towering waterfalls and lush grassy swamps.

While the Nile flows through many countries including Uganda, Sudan and Ethiopia – among others – the country it is most affiliated with is Egypt, the most northerly and the last it passes on its course to the Mediterranean. ▶

5 TOP FACTS
NILE KNOWLEDGE

Origins
1 It has been suggested that the River Nile was created in its modern incarnation approximately 25,000 years ago when Lake Victoria developed a northern outlet.

Vast Victoria
2 The primary source of the Nile is Lake Victoria, which covers an area of more than 69,400 square kilometres (26,795 square miles). Despite its size, it is very shallow and warm.

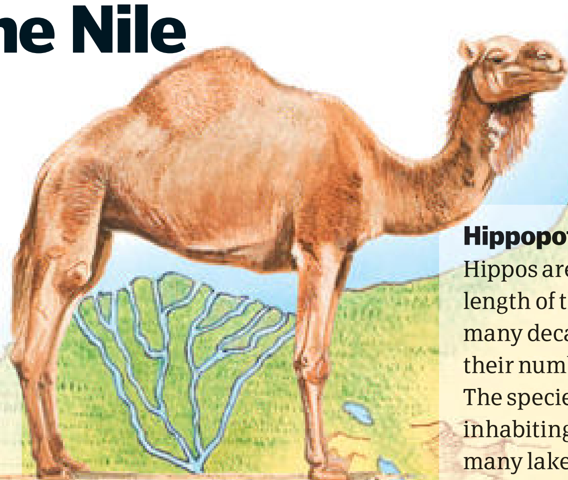
Dam pollution
3 While the construction of the Aswan Dam has prevented the Nile from flooding yearly in Egypt, it has also reduced its fresh water flow, in turn increasing pollution content.

Back to black
4 In Ancient Egyptian times the River Nile was known as 'Ar', or 'Aur', which translates as 'black', referring to the dark, fertile sediment that was left behind after it flooded.

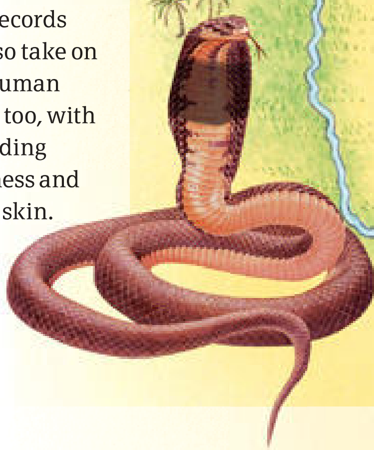
Delta
5 According to Greek geographer Strabo, the Nile Delta used to comprise seven delta distributaries. Today there are only two: the Rosetta and Damietta.

DID YOU KNOW? *The name 'Nile' is derived from the Greek 'Neilos', which means 'river valley'*

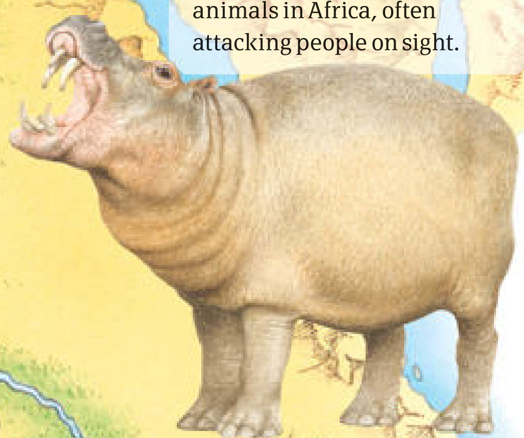
Beasts of the Nile



Dromedary camel
The second-largest species of camel, the dromedary has come to be a key image associated with Egypt. They are technically Arabian in origin but are now kept and used domestically throughout Egypt. They are commonly used to transport both goods and people, and are also a popular source of milk.



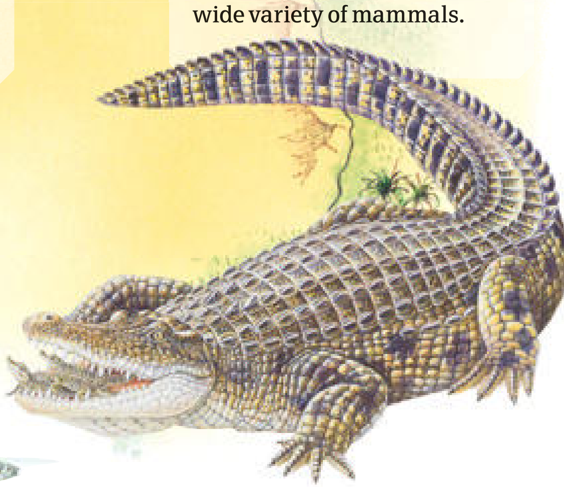
Red spitting cobra
This venomous snake is a native resident of Egypt's southern regions. It preys primarily on amphibians like frogs, however records indicate they will also take on birds and rodents. Human attacks are recorded too, with bite symptoms including muscle pain, numbness and disfigurement of the skin.



Hippopotamus
Hippos are found the entire length of the Nile, but due to many decades of poaching, their numbers are dwindling. The species is semi-aquatic, inhabiting the river itself, its many lakes and swamps as well as the fertile banks. They are one of the most aggressive animals in Africa, often attacking people on sight.

Grey heron
A large bird that frequents various parts of Africa, the grey heron is a common sight along the length of the river. Standing at approximately 100 centimetres (39 inches) tall and sporting a pinkish-yellow bill, the heron can typically be found on the Nile's banks and throughout the Egyptian Delta, where it feeds on fish, frogs and insects within the shallow waters. The bird appears in a lot of Ancient Egyptian artwork.

Nile crocodile
A dark bronze-coloured species of reptile, Nile crocodiles frequent the banks of the river throughout Egypt and other east African countries. These crocodiles are the largest found in the continent and are agile and rapid predators, feeding on a wide variety of mammals.



A desert oasis

1 Papyrus
This species of aquatic flowering plant belongs to the sedge family. The tall leafless grass has a greenish cluster of stems at its tip and has been used historically to produce papyrus paper.

2 Plume thistle
Found all over Egypt, but especially around the Nile, the plume thistle is a tall biennial plant that consists of a rosette of leaves, a taproot and a flowering stem. Traditionally, the stems were peeled and boiled for consumption.

3 Chamomile
This is a daisy-like plant from the family Asteraceae. There are many species of chamomile, however the one common to the Nile is Matricaria – a type commonly used in herbal remedies.

4 Blue Egyptian water lily
The 'blue lotus' is one of the most iconic plants on the Nile. With broad leaves and colourful blue blooms, this water lily stands out amid the sandy tones of Egypt. It had a spiritual link to the Ancient Egyptian deity Nefertem.

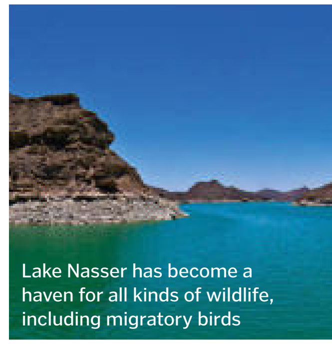
5 Opium poppy
As the name suggests this is the species of poppy from which opium is derived – the source of narcotics like morphine. The plant has blue-purple or white flowers and silver-green foliage.

"Flooding sees the Nile's total inflow rise from 45.3 million cubic metres per day to 707.9 million"

It is here in Egypt that historically the Nile was at its most variable, with the river flooding annually. While the river still floods, thanks to the construction of the Aswan Dam and Lake Nasser, it only does so in southern Egypt, with the lower-lying north remaining relatively protected.

The flooding is largely caused by the rainy season in the Ethiopian Plateau, an area from which both the Blue Nile and Atbara draw their water. As such, when the floodwaters enter Lake Nasser in late-July, the Blue Nile accounts for 70 per cent of all water, the Atbara 20 per cent, with the White Nile only accounting for ten. This flooding sees the Nile's total inflow rise from 45.3 million cubic metres (1.6 billion cubic feet) per day up to a whopping 707.9 million cubic metres (25 billion cubic feet).

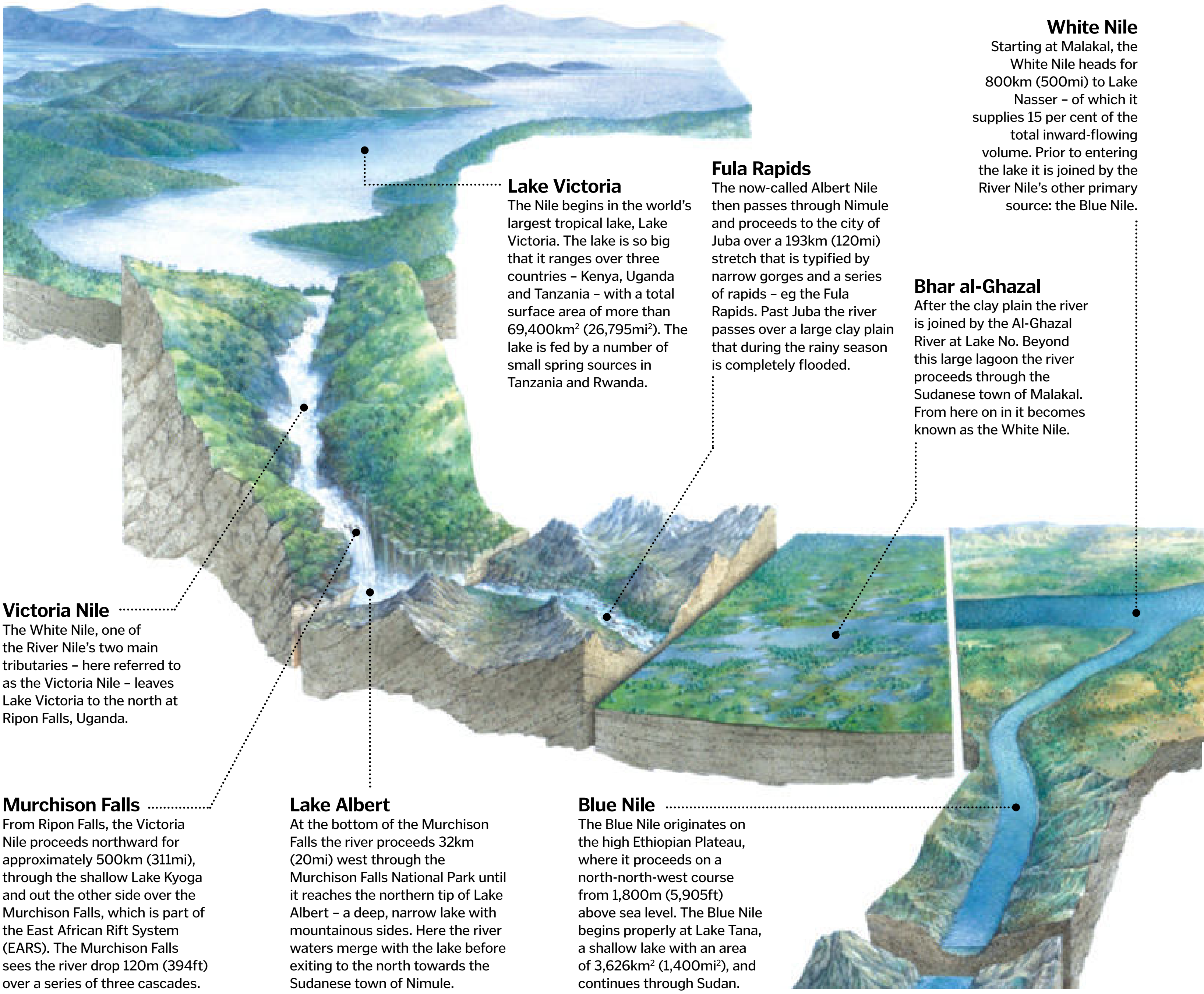
Crucially, while the dam at Aswan prevents annual flooding in Egypt, it does not stop its historical uses, which remain to this day incredibly wide ranging. The Nile is used as a source of irrigation for crops, water for industrial applications, transportation via boat and the cultivation of region-specific goods like papyrus. It's also an ecosystem for many unique plants and animals and a vital source of power, driving turbines that generate electricity.



Lake Nasser has become a haven for all kinds of wildlife, including migratory birds

Journey down the Nile

Take a grand tour down the River Nile from its main origin in Lake Victoria through to the Mediterranean



Lake Victoria
The Nile begins in the world's largest tropical lake, Lake Victoria. The lake is so big that it ranges over three countries – Kenya, Uganda and Tanzania – with a total surface area of more than 69,400km² (26,795mi²). The lake is fed by a number of small spring sources in Tanzania and Rwanda.

Fula Rapids
The now-called Albert Nile then passes through Nimule and proceeds to the city of Juba over a 193km (120mi) stretch that is typified by narrow gorges and a series of rapids – eg the Fula Rapids. Past Juba the river passes over a large clay plain that during the rainy season is completely flooded.

White Nile
Starting at Malakal, the White Nile heads for 800km (500mi) to Lake Nasser – of which it supplies 15 per cent of the total inward-flowing volume. Prior to entering the lake it is joined by the River Nile's other primary source: the Blue Nile.

Bhar al-Ghazal
After the clay plain the river is joined by the Al-Ghazal River at Lake No. Beyond this large lagoon the river proceeds through the Sudanese town of Malakal. From here on in it becomes known as the White Nile.

Victoria Nile
The White Nile, one of the River Nile's two main tributaries – here referred to as the Victoria Nile – leaves Lake Victoria to the north at Ripon Falls, Uganda.

Murchison Falls
From Ripon Falls, the Victoria Nile proceeds northward for approximately 500km (311mi), through the shallow Lake Kyoga and out the other side over the Murchison Falls, which is part of the East African Rift System (EARS). The Murchison Falls sees the river drop 120m (394ft) over a series of three cascades.

Lake Albert
At the bottom of the Murchison Falls the river proceeds 32km (20mi) west through the Murchison Falls National Park until it reaches the northern tip of Lake Albert – a deep, narrow lake with mountainous sides. Here the river waters merge with the lake before exiting to the north towards the Sudanese town of Nimule.

Blue Nile
The Blue Nile originates on the high Ethiopian Plateau, where it proceeds on a north-north-west course from 1,800m (5,905ft) above sea level. The Blue Nile begins properly at Lake Tana, a shallow lake with an area of 3,626km² (1,400mi²), and continues through Sudan.

THE STATS
NILE IN NUMBERS

LENGTH 6,650km | AVERAGE DISCHARGE $2,830m^3/s$ | BASIN AREA 3.4mn km^2

WIDTH 2.8km | PRIMARY SOURCE ELEVATION 2,700m | SECONDARY SOURCE ELEVATION 1,800m

DID YOU KNOW? *The White Nile has an almost constant volume, while the Blue Nile's is much more variable*

Egypt's ancient capital city, Cairo, is situated on the banks of the Nile

Search for the source

While today the sources of the Nile are well documented and clearly visible by satellite imagery, before the advent of such technology its source remained one of the planet's greatest mysteries, with various historians, geographers and philosophers speculating on its origin.

Arguably the earliest attempt to discern the source of the Nile was undertaken by Greek historian Herodotus (circa 484-425 BCE), who as part of his *Histories* recounts theories he gathered from several Egyptians. Unfortunately, while many of the tales are accurate to a point – with most describing the Nile to around modern-day Khartoum – none reveal its true origins, with Herodotus assuming it must begin in Libya.

This confusion and speculation continued with the Romans, with natural philosopher Pliny the Elder (23-79 CE) picking up from Herodotus stating the Nile's origin lay 'in a mountain of Lower Mauretania' – an area that correlates with modern-day Morocco. Indeed, this confusion remained right up until the 19th century, when a series of European-led expeditions slowly began to unearth the truth. These expeditions came to a head in 1875, when the Welsh-American journalist and explorer Henry Morton Stanley (1841-1904) confirmed that the White Nile, which was considered the one and true source, did indeed emanate from Lake Victoria in Uganda.

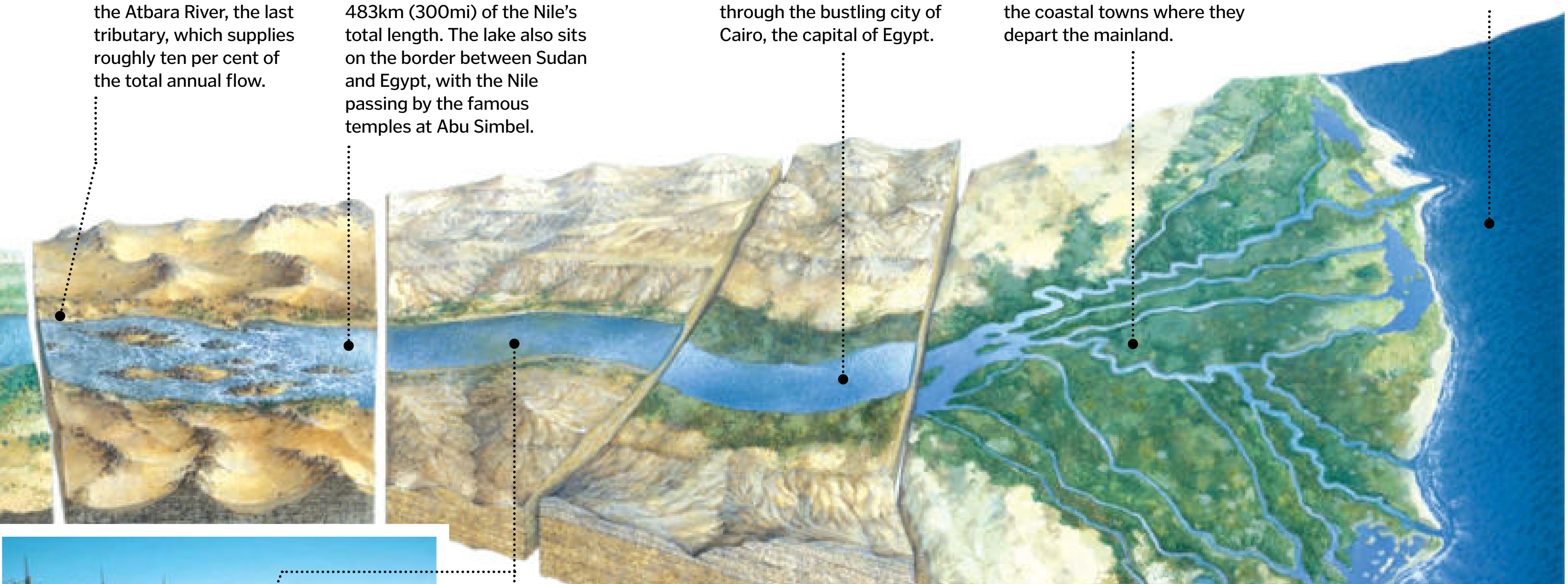
Khartoum
Near Khartoum the two primary rivers converge to create the River Nile proper, and proceed north for 322km (200mi). At this point the Nile is joined by the Atbara River, the last tributary, which supplies roughly ten per cent of the total annual flow.

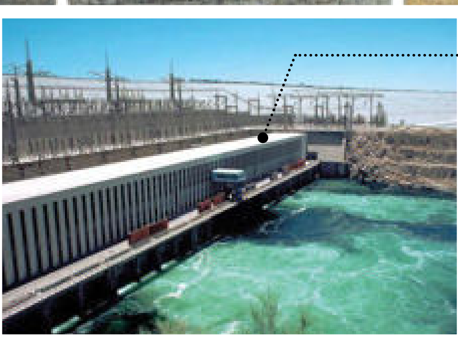
Lake Nasser
The Nile then enters Lake Nasser, the second-largest man-made lake in the world. With a potential maximum area of 6,735km² (2,600mi²), it covers approximately 483km (300mi) of the Nile's total length. The lake also sits on the border between Sudan and Egypt, with the Nile passing by the famous temples at Abu Simbel.

Cairo
For 322km (200mi) after the Aswan Dam the River Nile passes through an underlying limestone plateau, which averages 19km (12mi) in width. After another 322km (200mi) the river flows through the bustling city of Cairo, the capital of Egypt.

Nile Delta
After flowing through Cairo the River Nile enters a delta region, a triangular-shaped lowland where the river fans out into two main distributaries: the Rosetta and the Damietta. These distributaries are named after the coastal towns where they depart the mainland.

Mediterranean
Finally, after around 6,650km (4,130mi), the Nile comes to an end in the Mediterranean Sea, a body of seawater that spans 2.5mn km² (965,000mi²).





Aswan Dam
The cause of the vast Lake Nasser, the Aswan Dam is a huge embankment situated across the Nile at Aswan, Egypt. The dam was built to control the river's annual tendency to flood the lowlands of central Egypt in late-summer. The Nile's flow is controlled through the dam, continuing on a northwards course towards Cairo.

5 TOP FACTS IN THE O-ZONE

Stratosphere
1 The ozone layer is located in the lower stratosphere, a calm atmospheric region between the troposphere and the mesosphere which is not affected by weather or winds.

CFCs last for ages
2 While the use of CFC-causing products has reduced since 1970, CFCs have a long lifetime and so ozone depletion will continue for several decades yet.

Dissociation
3 Ozone causes that funny smell after a storm. The electrical breakdown of oxygen helps ozone to form. Because ozone is denser it sinks to ground level where we can smell it.

Record hole
4 NASA is keeping close tabs on the ozone over Antarctica. The largest hole recorded to date was in 2000 at 29.9 million square kilometres (11.5 million square miles).

When ozone goes bad
5 Ozone is good as long as it stays in the stratosphere where it protects us from the Sun. But if human pollutants increase ozone near the ground it can become harmful.

DID YOU KNOW? Ozone concentration is measured in Dobson units (DU), named after British meteorologist Gordon Dobson

Why are there holes in the ozone layer?

The creation and destruction of ozone in Earth's atmosphere explained

Held in place by gravity, Earth's atmosphere is a thick protective shield that extends 400 kilometres (270 miles) out from the planet's surface. In the lower stratosphere – at a height of between 15 and 50 kilometres (9 and 30 miles) – is a layer of ozone (O_3), which is a colourless but highly reactive gas. This 'ozone layer', which varies in concentration, provides a natural sunscreen for Earth against the Sun's potentially harmful ultraviolet (UV) radiation. While UV does have a positive effect on the body – it stimulates the production of vitamin D – overexposure damages skin cells. So the depletion of this protective gaseous layer has very serious implications for life on Earth.

Every spring high over Antarctica, and to a lesser extent in the Arctic, the ozone layer thins so that 'holes' appear. As a result there is less protection against UV radiation, and geoscientists are monitoring this closely.

While a normal oxygen molecule (O_2) consists of two oxygen atoms, ozone (O_3) has three. Most of the ozone in the stratosphere is created when powerful solar photons break the bonds inside O_2 molecules, freeing individual oxygen atoms (O), which can then rejoin normal O_2 atoms to create O_3.

The main offenders in the depletion of ozone are chlorofluorocarbons (CFCs), which are now banned in many countries. These organic carbon, fluorine and chlorine compounds are produced by man-made substances like refrigerants and the propellant in aerosol cans. When released into the atmosphere these CFCs then accumulate in the stratosphere. Cold temperatures over Antarctica cause the formation of polar vortices, which create high-altitude ice clouds. When the Sun's light hits these clouds the CFCs convert into a highly reactive form of chlorine that destroys ozone.

While the holes diminish in size during the warmer months, every spring the ozone layer in both the Antarctic and Arctic regions shrinks. CFC pollutants have been greatly reduced since their damage was discovered in the Seventies, but it will take a long time for the CFCs to completely deteriorate.

Why is ozone so thin at the poles?

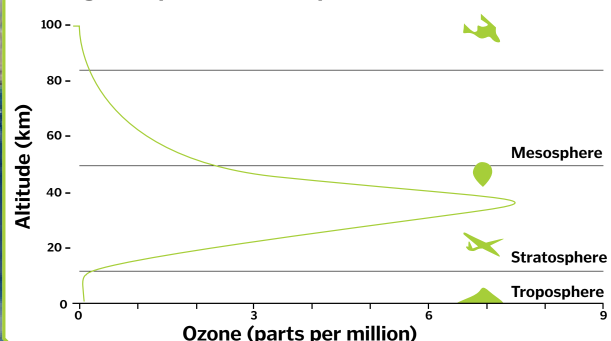
The presence of CFCs
There's a lot of chlorine and bromine in the stratosphere. 80 per cent of Antarctica's chlorine comes from CFCs.

It's cold at the poles
The cold temperatures at Earth's polar extremes cause stratospheric polar clouds whose particles react chemically to release chlorine in a form that destroys ozone.

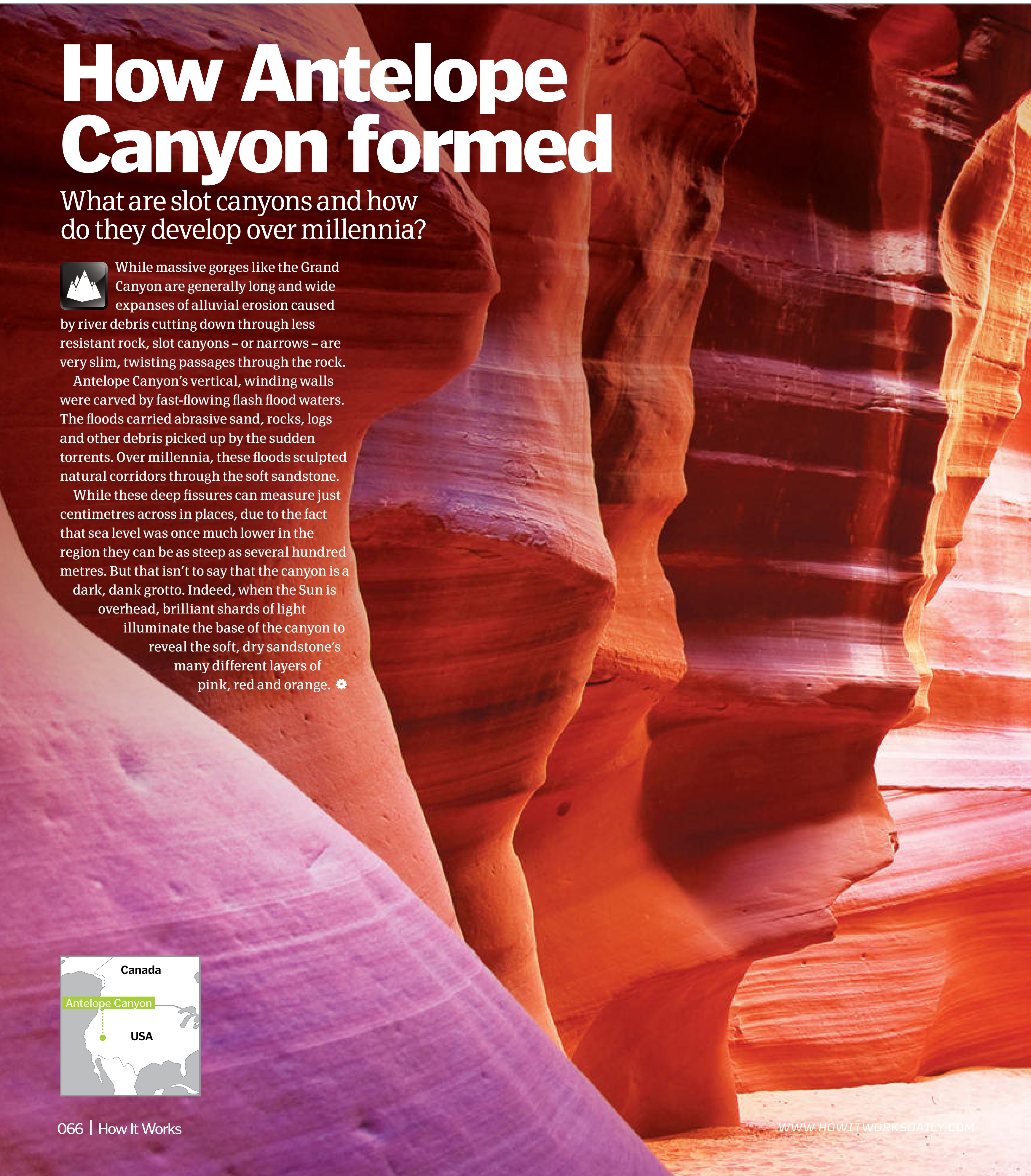
Sunlight is the catalyst
The energy from the Sun over Antarctica in August/September (ie spring) is a catalyst for a reaction that sees a single chlorine molecule destroy thousands of ozone molecules.

Ozone concentration

Take a look at how ozone is distributed through our planet's atmosphere



"It features vertical, winding walls that were carved by fast-flowing flash flood waters"



How Antelope Canyon formed

What are slot canyons and how do they develop over millennia?

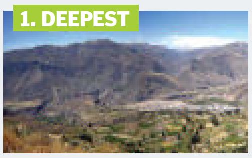
While massive gorges like the Grand Canyon are generally long and wide expanses of alluvial erosion caused by river debris cutting down through less resistant rock, slot canyons – or narrows – are very slim, twisting passages through the rock.

Antelope Canyon's vertical, winding walls were carved by fast-flowing flash flood waters. The floods carried abrasive sand, rocks, logs and other debris picked up by the sudden torrents. Over millennia, these floods sculpted natural corridors through the soft sandstone.

While these deep fissures can measure just centimetres across in places, due to the fact that sea level was once much lower in the region they can be as steep as several hundred metres. But that isn't to say that the canyon is a dark, dank grotto. Indeed, when the Sun is overhead, brilliant shards of light illuminate the base of the canyon to reveal the soft, dry sandstone's many different layers of pink, red and orange.

HEAD 2 HEAD
MEGA-CANYONS

1. DEEPEST



Cotahuasi Canyon
This Peruvian canyon is thought to be Earth's deepest at 3,500 metres (11,500 feet) – over twice the Grand Canyon's depth!

2. WIDEST

Capertee Valley
Again outdoing the famous Grand Canyon, Capertee in Australia is regarded as the widest canyon in the world.

3. LONGEST

Valles Marineris
The largest canyon in the Solar System is the Valles Marineris, which spans over 4,000 kilometres (2,485 miles) on Mars.

DID YOU KNOW? *The 2010 film 127 Hours portrayed the real-life story of canyoneer Aron Ralston who got trapped in a slot canyon*

The Navajo name for Antelope Canyon is Tsé Bighánílíní, which translates as 'the place where water runs through rock'

5 TOP FACTS
HAGFISH TRIVIA

Enigma
1 This is the only species we know capable of regulating its own oxygen intake and transporting it to different parts of the body. Science can't explain how this is possible.

Habitat
2 You can find hagfish all around the planet swimming in cool seas and burrowing into the soft-bottomed ocean floors at depths of about 1,300 metres (4,265 feet).

Spineless
3 The lack of a spinal column means that the hagfish is extremely flexible. It can even tie itself up in knots in order to scrape the slime off its body and escape danger.

Fearless
4 Hagfish do not fear enemies much larger than themselves. Sharks and any other killers that might foolhardily go in for the kill are often choked in seconds by their slime.

Inside and out
5 To consume its prey (which is often dead or dying) not only does it scrape the flesh away with its teeth, but it can also crawl inside the creature and eat its way out from inside.

DID YOU KNOW? A hagfish can go for at least six months without feeding!

How do hagfish survive?

Learn why this marine invertebrate squirts slime on any predators who get too close

The hagfish might seem like an innocent-looking eel, but this 300-million-year-old, soft-skinned fish has survived the test of time due to a deadly – not to mention utterly revolting – self-defence mechanism. The hagfish has no scales, jaw, venom or spinal column, but it has the power to suffocate its enemies in a flash with the help of a choking slime squirted from vesicles down the length of its body. In fact, the hagfish can 'slime' a predator in under half a second.

When the fish is physically disturbed – by a strike from an attacker, for example – the slime gland is triggered to shoot out mucus proteins called mucins, which when combined with seawater immediately turn into a thick goo.

What's inside a compost bin?

Find out how a pile of old leaves and veg peelings can help beautiful gardens grow

Compost is an earthy mass of decomposed plant material that can be added to gardens and planters to improve soil structure and provide a small amount of nitrogen essential for plant growth. Layering organic matter such as leaves, vegetable peelings, grass cuttings and even eggshells into the heap results in the gradual breakdown of matter over a few weeks.

Micro-organisms within the bin set about decomposing the organic materials and, in doing so, release nutrients back into the soil. Conditions inside the heap need to be just right in order to aid the efficient breakdown of materials and release of nutrients.

"Around 85 per cent of the phosphorus in our bodies can be found in our teeth and bones"

The phosphorus cycle

Why is this element so important to life and how is it processed by nature?

Phosphorus is a crucial element to life, whether an organism is a member of the plant or animal kingdom. It forms a fundamental component of genes – the DNA and RNA structure that determines what we are – and it also plays a major role in the ATP (adenosine triphosphate) energy cycle, without which we wouldn't be able to contract our muscles. In vertebrates like us mammals, around 85 per cent of the phosphorus in our bodies can be found in our teeth and bones.

Phosphorus goes through a cycle similar to that of carbon, nitrogen and sulphur. However, unlike these important systems, because of the Earth's normal range of temperatures and pressures, hardly any of the phosphorus on our planet exists as a gas. Instead, most of it is bound up in sedimentary rock and a small proportion in water, although phosphorus isn't very soluble in H_2O and tends to bond more readily to molecules in the soil, entering watery ecosystems as part of runoff particles.

Phosphorous minerals, called phosphates, enter the food chain from rocks via weathering. Plants absorb the phosphorus ions in the soil, herbivores ingest phosphorus by eating the plants and, in turn, carnivores absorb it from herbivores. It's then returned to the cycle via excretion and decomposition. Fertilisers, sewage and, formerly, detergents can all create an excess of phosphorus in the cycle, which can cause 'blooms' of suffocating algae and choking weeds in the sea and other bodies of water.

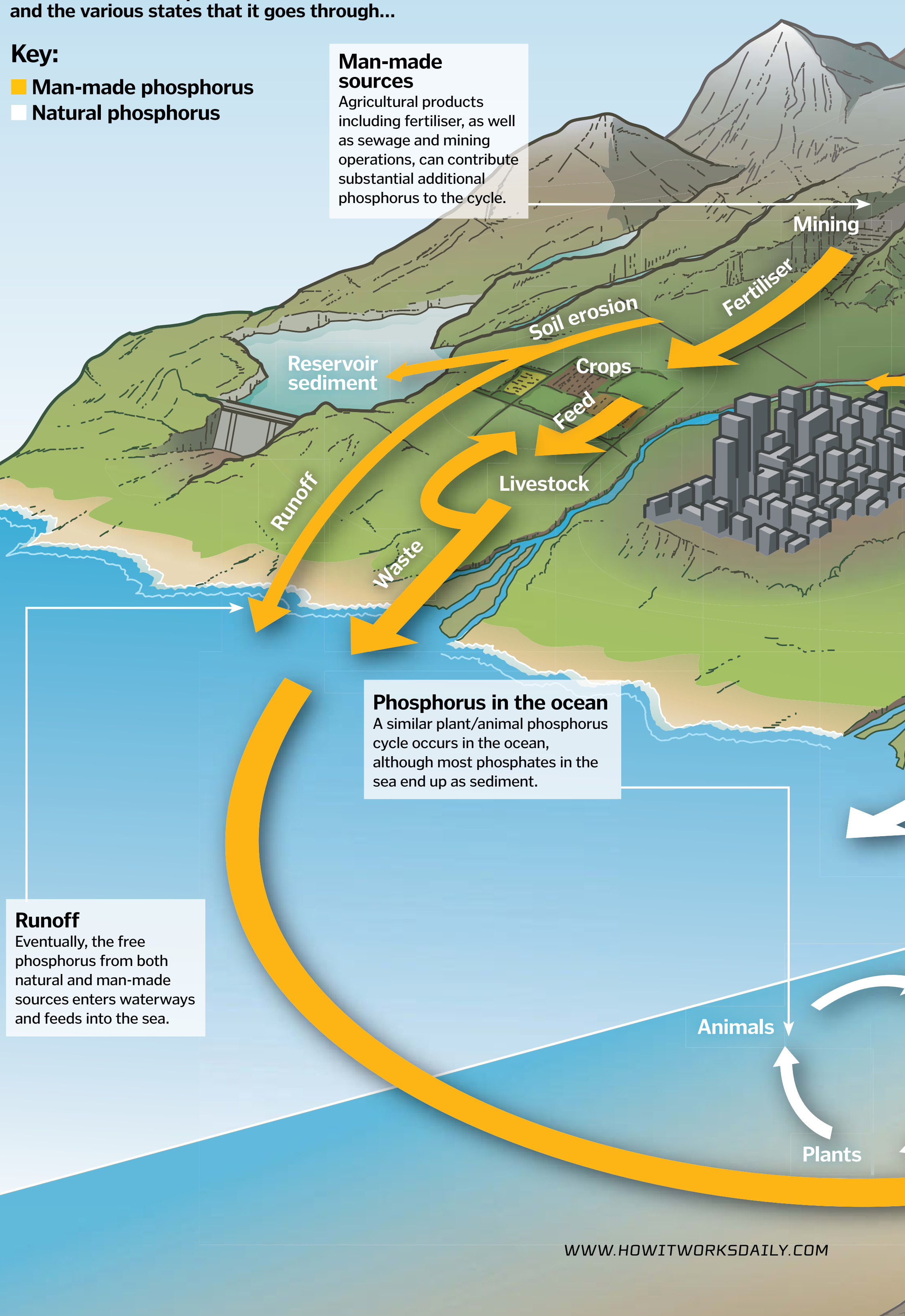
A dangerous gas

The gaseous form of phosphorus – phosphine – is usually only found under lab conditions as hydrogen phosphide (PH_3) and is completely odourless in its pure form, although it has a strong rancid fish or garlic smell in its impure diphosphane form. Phosphine is also extremely flammable and toxic; concentrations as low as one part per million can quickly cause a number of short-term symptoms, including vomiting and breathing difficulties. Higher concentrations can cause permanent damage and even death. It does have a use in industry, however, playing a role in the manufacture of semiconductors (components vital to the electronics field) and also in pest control. In the latter it's found as a gaseous fumigant or as phosphide pellets, treated to prevent the gas from exploding, which kill pests like rodents when inhaled/consumed.

How phosphorus is recycled

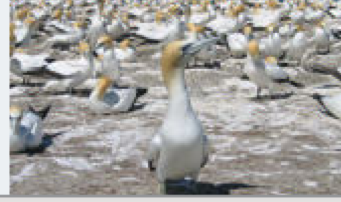
Discover where this prolific element comes from and the various states that it goes through…

Key:
- Man-made phosphorus
- Natural phosphorus



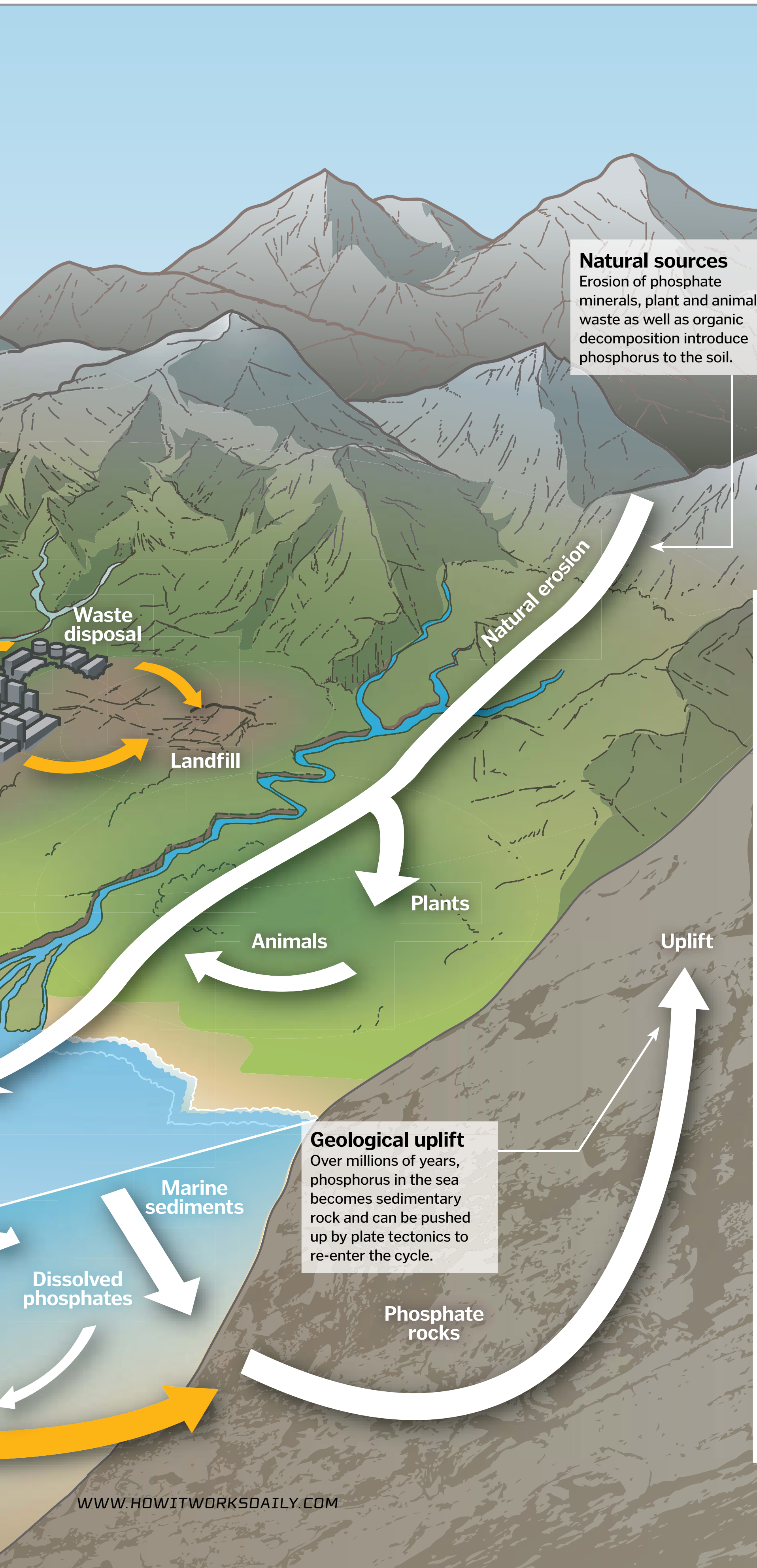
Which avian product is a rich source of phosphorus?

A Bird feathers **B** Bird poo **C** Bird eggs



Answer:
In 1840, guano (bird droppings) was identified as a ready source of phosphorus and saltpetre, or nitre, which is used for making gunpowder. It prompted the Guano Islands Act, allowing the US to claim any unowned isle/rock with guano deposits.

DID YOU KNOW? *Early match industry workers were subject to 'phossy jaw', a disease that made the jaw glow and decay*



Discovery of phosphorus

Phosphorus was first discovered as an element in the 17th century. It was the 13th element to be found but the first since bismuth was discovered in ancient times. In 1669, German alchemist Hennig Brand came upon phosphorus when experimenting with urine in pursuit of creating the fabled philosopher's stone – the substance that was widely thought to facilitate the transmutation of metals like lead into gold or silver. Brand boiled litres of urine down into a paste that he heated through water, allowing its vapours to condense. Instead of gold, he got a waxy white substance that glowed in the dark: a phosphorous compound called ammonium sodium hydrogen phosphate. The glow that comes from white phosphorus is a slow reaction with oxygen that takes place at the surface of the element, which creates molecules that emit a visible wavelength of light. White phosphorus was used in matches for a time before it was removed because of its toxicity.

Strip-mining for phosphate near Tampa, FL. Florida provides about 25 per cent of global phosphorus production

The Palace of Westminster

Known as the 'Mother of Parliaments', Westminster's iconic architecture is recognised throughout the world

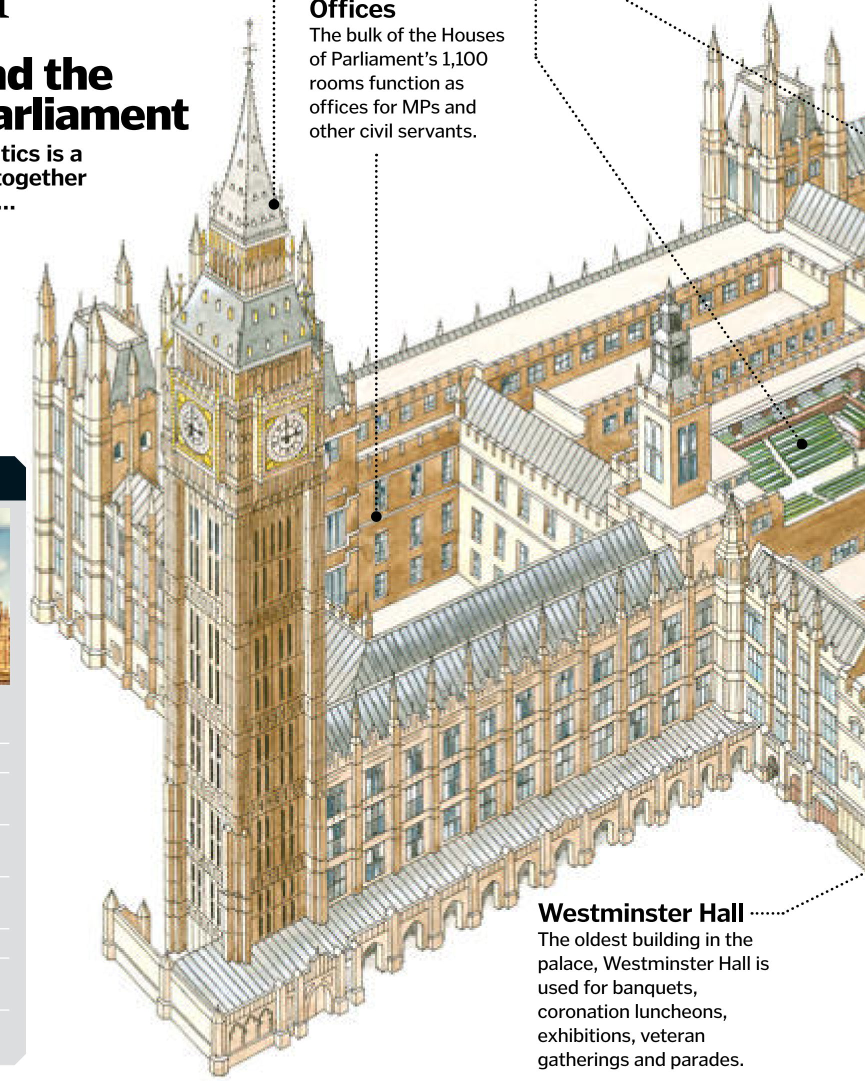
The Palace of Westminster was established by King Canute in the early-11th century and much expanded by Edward the Confessor after his coronation in 1042. After the Norman Conquest, William I adopted Westminster to help validate his new regime and his son, William Rufus, built the great hall (Westminster Hall). At the time of its construction, this hall was the largest of its kind in Europe and remains so to this day.

Under King Henry III Westminster became increasingly important as a central hub of royal power. He had a set of splendid apartments built which included the Painted Chamber, an enormous rectangular room which housed the monarch's state bed. The bedroom's decoration was so detailed that it took over 60 years to paint. Although much degraded and damaged over the centuries, the Painted Chamber survived for more than 600 years until it was demolished in the catastrophic fire of 1834.

The medieval palace's other focal point was the magnificent St Stephen's Chapel. First mentioned in 1184, it was rebuilt by Edward I in the mid-13th century to rival the Sainte-Chapelle in Paris, before being remodelled by Edward III. It was finally completed in 1363. Thought to be the first building constructed in the English Perpendicular Gothic style, the chapel was served by the canons of St Stephen's College. Westminster remained the English monarchy's principal royal residence ▶

A tour around the Houses of Parliament

The heart of British politics is a maze-like building put together over hundreds of years…



The statistics…

The Palace of Westminster

Architect: Sir Charles Barry

Years of construction: 1840-1870

Type of building/purpose: Parliament building

Location: The City of Westminster, London, UK

Full height: 98.5m (323ft)

Area of site: 3.2 hectares (8 acres)

Cost of construction: £2m (over £100m/$160.5m today)

Parliament in progress

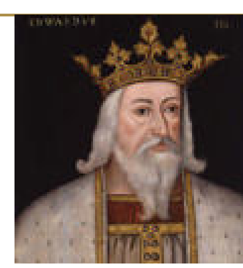
We pick just a few of the notable dates in the Palace of Westminster's long history

c. 1016
Foundations laid
King Canute builds a royal residence on Thorney Island, a former islet (or eyot) in the River Thames.

1097-9
Westminster Hall erected
William II – the son of William the Conqueror – builds Westminster Hall over three years.

1292
Chapel remodelled
King Edward I begins rebuilding St Stephen's Chapel located next to Westminster Hall.

1367
Time for a tower
Edward III (right) constructs Westminster's first clock tower in New Palace Yard.



HEAD2HEAD
PARLIAMENTARY BUILDINGS

1. BIG

Scottish Parliament
Covering an area of only 1.6 hectares (four acres) in central Edinburgh, the new Scottish Parliament was opened in 2004.

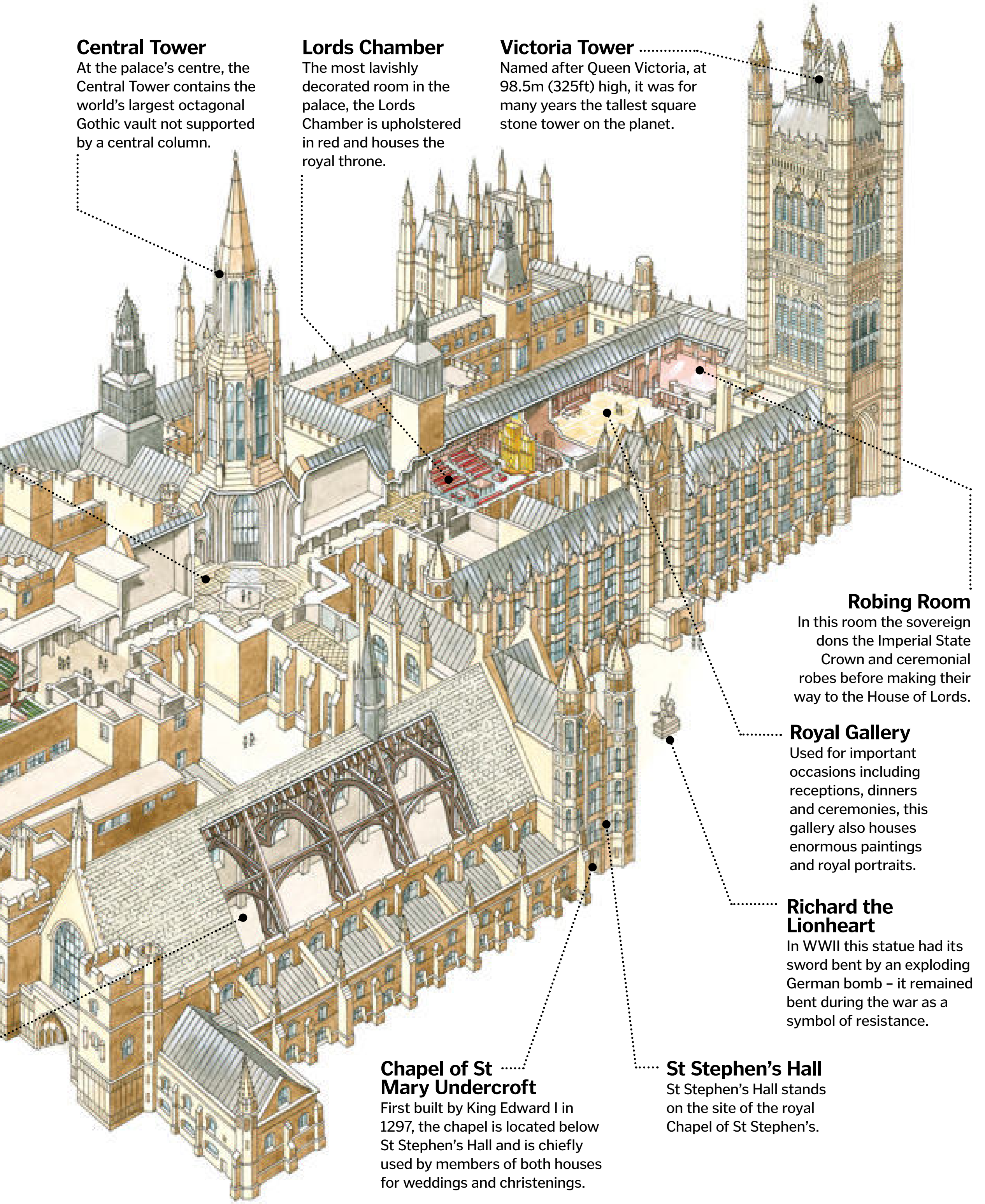
2. BIGGER

Parliament Hill
'The Hill' in Ottawa houses the three main Canadian parliament buildings. The entire complex fits into 8.8 hectares (21.9 acres).

3. BIGGEST

Parliament of Bangladesh
Containing Bangladesh's seven parliaments, this massive legislative complex covers 81 hectares (200 acres)!

DID YOU KNOW? *The lantern at the top of the Elizabeth Tower is only lit after dark when parliament is sitting*



Central Tower
At the palace's centre, the Central Tower contains the world's largest octagonal Gothic vault not supported by a central column.

Lords Chamber
The most lavishly decorated room in the palace, the Lords Chamber is upholstered in red and houses the royal throne.

Victoria Tower
Named after Queen Victoria, at 98.5m (325ft) high, it was for many years the tallest square stone tower on the planet.

Robing Room
In this room the sovereign dons the Imperial State Crown and ceremonial robes before making their way to the House of Lords.

Royal Gallery
Used for important occasions including receptions, dinners and ceremonies, this gallery also houses enormous paintings and royal portraits.

Richard the Lionheart
In WWII this statue had its sword bent by an exploding German bomb – it remained bent during the war as a symbol of resistance.

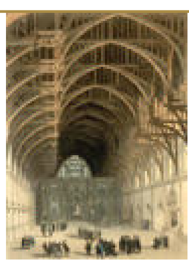
Chapel of St Mary Undercroft
First built by King Edward I in 1297, the chapel is located below St Stephen's Hall and is chiefly used by members of both houses for weddings and christenings.

St Stephen's Hall
St Stephen's Hall stands on the site of the royal Chapel of St Stephen's.

Big Ben in focus

Although the name 'Big Ben' is often used to describe Westminster's clock tower, it is actually called the Elizabeth Tower. While the bell is officially called the Great Bell of Westminster, it's generally referred to as Big Ben – a nickname of uncertain origin now known all over the world. The Elizabeth Tower was designed by the architect Augustus Pugin and completed in 1859; it contains 11 floors and there are 334 steps to the belfry. The belfry houses the Great Clock of Westminster, built by Edward John Dent and his sons. Striking the hour to within a second of the time, the Great Clock has remained reliable since it entered service in 1859. The time is shown on four dials, each seven metres (23 feet) in diameter, which are made of opalescent milk glass and can be lit from behind at night. The hour hand is 2.7 metres (8.9 feet) long, while the minute hand measures 4.2 metres (13.7 feet). The Great Clock started ticking on 31 May 1859, with the Great Bell's strikes heard for the first time on 11 July the same year. The Great Bell weighs 13.7 tons, is 2.2 metres (7.2 feet) in height and produces the note 'E' when tolled. Big Ben is fixed and struck by hammers from outside rather than swinging and being struck from inside by clappers. There are four other bells in the belfry and, when rung together, they produce the 'Westminster chimes'.

1394-99
Westminster Hall rebuilt
Richard II rebuilds Westminster Hall in its present form.



1512
Parliament arrives
The palace becomes the permanent residence for the English parliament.

1547
Edward VI's gift
Henry VIII's son Edward VI gives St Stephen's Chapel to the Commons after the dissolution of the college.

1605
Gunpowder Plot
Guy Fawkes and fellow conspirators try to blow up the House of Lords, but Fawkes is caught red-handed.

> "Westminster's new design was so successful it influenced buildings throughout the British Empire"

throughout the medieval period until 1512, when Henry VIII abandoned it in favour of the nearby Palace of Whitehall.

In the Middle Ages parliament frequently met in Westminster Abbey's octagonal Chapter House – close to the Palace of Westminster – but in 1547 Edward VI closed St Stephen's College and gave the Commons the chapel as their permanent home. When the MPs moved in, they sat in the choir stalls and made speeches to each other across the chapel's central aisle. This arrangement may have encouraged the development of the two-party system of government versus opposition (see boxout) with which we are familiar today.

During the 17th and 18th centuries the medieval palace was gradually lost as various buildings were converted for new uses and its interiors redecorated. 'Improvements' were undertaken by architects such as Sir Christopher Wren, James Wyatt and Sir John Soane, which resulted in the palace gradually being transformed into a complex tangle of buildings. Then, on the night of 16 October 1834, a devastating fire broke out which destroyed the whole palace apart from Westminster Hall and a few minor buildings.

After the fire a competition was held for a new design and Sir Charles Barry's was chosen from a total of 97 entries. Barry's vision for Westminster in a Perpendicular Gothic style was in harmony with the surviving buildings and was also carefully designed to serve the day-to-day needs and workings of parliament. All in all the construction of the new palace took some 30 years. Its sumptuous interior decoration was the work of Augustus Welby Pugin, a gifted 23-year-old Roman Catholic architect and draughtsman. Westminster's new design was so successful that it not only influenced the designs of town halls, law courts and schools throughout the British Empire, but it also came to be recognised globally as an architectural masterpiece.

Today, after all these centuries, the Palace of Westminster remains at the heart of UK government. It contains over 1,100 rooms, 100 staircases and some 4.8 kilometres (three miles) of passageways which are spread over four floors. Despite being over 170 years old, the palace still functions smoothly, acting as a backdrop for both the cut and thrust of modern politics and royal ceremonial life, such as the state opening of parliament. Still officially a royal residence after almost a thousand years, the Palace of Westminster was designated a UNESCO World Heritage Site in 1987, as a seminal example of neo-Gothic architecture.

Of gunpowder and treason

The Gunpowder Plot of 1605 was a failed assassination attempt against King James I of England (or James VI of Scotland) by a group of English Catholics led by Robert Catesby. The plan was to blow up the House of Lords during the state opening of parliament on 5 November 1605, as the prelude to a popular revolt in the Midlands during which James's nine-year-old daughter, Princess Elizabeth, was to be installed as the Catholic head of state. The conspirators thus hoped that England would once more become a Roman Catholic country.

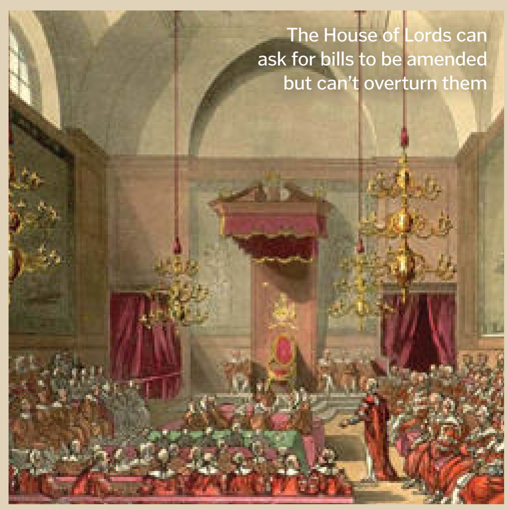
One of the conspirators – Guy Fawkes, who had ten years' military experience abroad – was put in charge of the explosives. These were then secretly smuggled into the palace. However the plot was revealed to the authorities and, during a search of the House of Lords at about midnight on 4 November 1605, Fawkes and 36 barrels of gunpowder were discovered. This was enough explosive to reduce the House of Lords to rubble and kill all within it. Most of the conspirators fled from London but were soon captured. At their trial on 27 January 1606, the conspirators were convicted and sentenced to be hanged, drawn and quartered. The thwarting of the Gunpowder Plot was widely celebrated and it's known to this day as Bonfire Night.

The two-house system

The Westminster parliament comprises two 'houses': the House of Commons (the lower house), consisting of 650 members (MPs) elected by their constituencies, and the House of Lords (the upper house), consisting of life peers, hereditary peers and Lords Spiritual (bishops of the Church of England). At present the House of Lords has 775 members.

The purpose of parliament is to govern the country in the monarch's name and this falls to the largest party in the Commons (or a coalition of parties as at present). Legislation once passed by the Commons goes on to the Lords. The upper house can scrutinise and delay legislation, but since the Parliament Act of 1911, the Lords cannot reject it. The government is primarily responsible to the House of Commons and the prime minister stays in office only so long as he or she retains its support.

New bills are put to elected MPs in the House of Commons and voted on



The House of Lords can ask for bills to be amended but can't overturn them

1649

Fate of a king

Charles I (right) is condemned to death in Westminster Hall after his defeat in the English Civil War.

1834

The Great Fire

The Palace of Westminster, dating from medieval times, is destroyed by fire.

1835

Competition

Sir Charles Barry wins a competition to rebuild the palace in a Gothic-revival style.

1840

The first stone

The first stone of the new palace is laid by Charles Barry's wife in the north-east corner of the building.

STRANGE BUT TRUE
A LAW UNTO THEMSELVES

What can MPs do in the House of Commons?

A Smoke **B** Take snuff **C** Eat popcorn

Answer:
Although smoking was banned in the House of Commons in the 17th century, the taking of snuff was allowed instead. To this day the doorkeepers of the Commons Chamber keep a full snuff-box should any MP wish to indulge in the habit.

DID YOU KNOW? *The Great Bell of Westminster is cracked, which is why it has such a distinctive resonant tone*

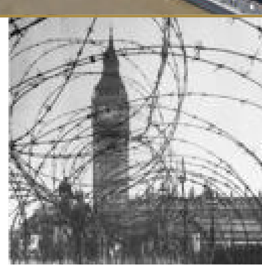
Surviving the Blitz

During the course of World War II, the Palace of Westminster was hit by German bombs on 14 separate occasions. The worst raid took place on the night of 10 May 1941, when the palace took at least 12 hits and three people were killed. An incendiary bomb struck the chamber of the House of Commons and set it on fire, while another set the roof of Westminster Hall alight. The firefighters could not save both and so the decision was taken to rescue the historically important hall. In this they were successful, but the abandoned Commons Chamber was completely gutted, as was the Members' Lobby. A bomb also struck the Lords Chamber, but luckily it went through the floor without exploding. The Elizabeth Tower (which houses Big Ben) was hit by a small bomb or shell just below the roof line and it suffered much damage as a result. All the glass in the south dial was blown out, but the hands and bells were not affected – amazingly, despite the explosion, the clock continued to keep time accurately. The Commons Chamber was rebuilt after the war by the architect Sir Giles Gilbert Scott. The reconstruction was in a simplified version of the old chamber's style, and it is Scott's chamber – not Augustus Pugin's – that we know today.

1859
Big Ben arrives
The bell that has famously come to be known as Big Ben is installed in the Elizabeth Tower.

1870
Westminster complete
The rebuilding of the new Palace of Westminster is completed.

1941
The Blitz
The Commons Chamber is destroyed on 10/11 May – the last day of the London Blitz.



2000
Portcullis House
A new parliamentary building to house Members of Parliament's offices is completed. It was officially opened by the Queen in 2001.

"If the user rotates the dial from '7', seven pulses will be sent down the line to the switching office"

Rotary dial telephones

For many decades our phones sported a spinning dial, but how did they work?

A rotary dial telephone was a popular type of phone design throughout the 20th century. This communication device dials numbers in a very different way to the more modern push-button systems we're familiar with today, requiring the user to rotate a numbered dial to key in digits rather than press a series of buttons.

The rotary dial works on a pulse-based system. The frequency of pulses is determined by the number on the dial which the caller selects, with the user manually turning the dial to a fixed point with their finger before releasing it. This causes the dial to return to its starting position due to an internal recoil spring, while simultaneously

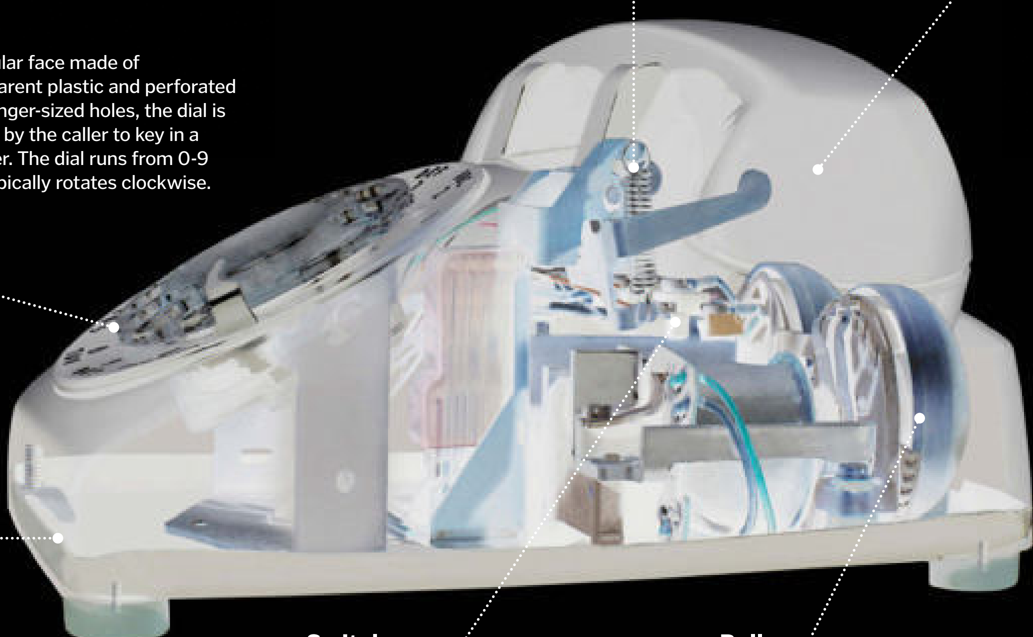
generating a series of electrical pulses that interrupt the flow of current on the telephone's line. These pulses correspond to the digit selected, so if the user rotates the dial from, say, '7', then seven pulses will be sent down the line to the switching office.

Inside the body of the phone a centrifugal governor ensures that the dial's rotation is moderated to a constant rate, with a shaft on the governor turning a cam that opens and closes a switch contact. If the contact is open, the line's current is stopped from flowing, thereby creating a dial pulse, while when closed, there is a constant flow of current.

At the electromechanical switching office, these pulses are received by a sender system, which records the pulses – ie the dialled number – before routing it to a selector system which makes the outgoing connection to the telephone of the appropriate property.

Making the call

Take a look at the main components that make up these traditional communication devices



Recoil spring
As the dial needs to be rotated a number of times, it connects to a spring. This returns the dial to its starting point and moderates its movement speed and the switch position via a governor and cam.

Receiver
As with a modern phone, the user speaks through a handheld receiver, with the handset comprising both receiver and transmitter ends. When resting on the phone's cradle, the line is in a receptive state.

Dial
A circular face made of transparent plastic and perforated with finger-sized holes, the dial is turned by the caller to key in a number. The dial runs from 0-9 and typically rotates clockwise.

Body
The body is faced with the dial mechanism and contains the core components of the system. It is generally made of moulded plastic like Bakelite, though early units were built from wood and metal.

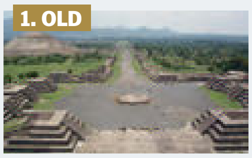
Switch
This electrical contact dictates the phone's pulse generation. When a user keys in a number, the movement of the dial forces the contact to open and close to create a specific number's dialling pulse.

Bell
When an incoming call is awaiting connection, a brace of mechanical bells at the rear of the body are struck by a hammer to produce a ringing noise. Once the handset is lifted, the hammer is disengaged.

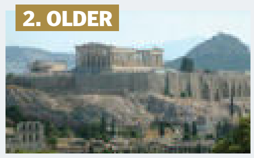
The rise of touch-tone

In 1950 US network operator AT&T ran a series of trials which proved that push-button dialling was roughly twice as efficient as rotary dialling. This led to the company releasing an electronic push-button system known as 'Touch-Tone' to its customers in 1963, which quickly gained popularity thanks to its speed – both at the user end and at the network end. The touch-tone system, which is still in use throughout the world today, works through dual-tone multi-frequency (DTMF) signalling where each of the dialling digit buttons is assigned a specific frequency; columns have higher-frequency tones while rows have lower ones. As such, when a button is pressed, a dual-tone signal is generated that corresponds directly to the frequency assigned to a specific telephone number.

HEAD 2 HEAD
ANCIENT RELIGIOUS SITES



1. OLD
Teotihuacán
Built around 110 BCE to 250 CE in central Mexico, this city contains the Pyramid of the Sun, which is the third-largest pyramid in the world.



2. OLDER
The Acropolis
Constructed circa 500 BCE, the Acropolis in Greece's capital, Athens, includes several temples – the most famous of which is the Parthenon.

3. OLDEST
Stonehenge
Believed to have been built circa 2500 BCE, this enigmatic religious monument consisting of rings of standing stones is found in Wiltshire, UK.

DID YOU KNOW? *In 1974 a statue in the pagoda was found to contain what's believed to be one of Buddha's original teeth!*

The Fogong Temple Pagoda

The oldest wooden pagoda in China today is an architectural marvel by anyone's standards

The pagoda, traditionally a tiered tower built of stone, brick or wood, originated in historic eastern Asia. Usually associated with Buddhism and used for the storing of relics and sacred writings, the pagoda's architectural form has since been adopted by other religions and modified for secular use throughout the world.

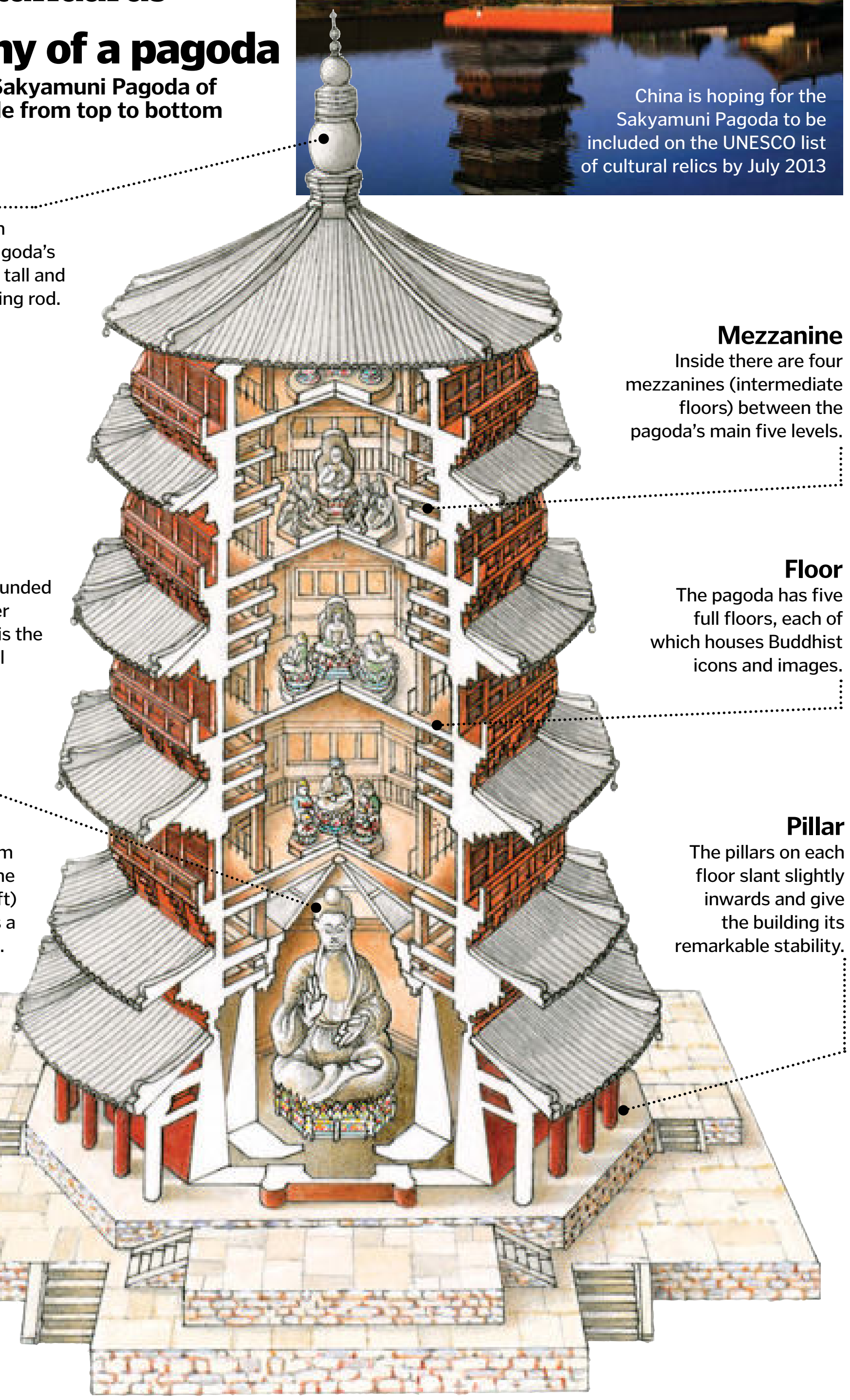
The Sakyamuni Pagoda of Fogong Temple forms the central element in a complex of buildings erected by the Chinese Emperor Daozong in 1056. Said to have been built on the site of his family home, the emperor was a devout Buddhist and demonstrated this through the erection of this remarkable wooden, nine-storey structure. Covered with a profusion of carved and painted decoration, the pagoda is supported by 24 exterior and eight interior pillars, and roofed with highly ornate and glazed ceramic tiles.

The pagoda has needed occasional minor repairs over its lifetime and, despite surviving numerous natural disasters, the only serious threat it has faced came during the Second Sino-Japanese War (1937-1945) when Japanese soldiers raked the structure with small-arms fire. Today, the Fogong Temple Pagoda is a popular tourist attraction rather than a religious site, but its cultural significance is recognised in both China and beyond.

China is hoping for the Sakyamuni Pagoda to be included on the UNESCO list of cultural relics by July 2013

Anatomy of a pagoda

Examine the Sakyamuni Pagoda of Fogong Temple from top to bottom



Steeple
The steeple which surmounts the pagoda's roof is 10m (33ft) tall and serves as a lightning rod.

Mezzanine
Inside there are four mezzanines (intermediate floors) between the pagoda's main five levels.

Statue of the Buddha
This statue, surrounded by images of other Buddhist deities, is the pagoda's principal devotional focus.

Floor
The pagoda has five full floors, each of which houses Buddhist icons and images.

Foundation
The stone platform which supports the pagoda is 4m (13ft) high and provides a stable foundation.

Pillar
The pillars on each floor slant slightly inwards and give the building its remarkable stability.

Built to last

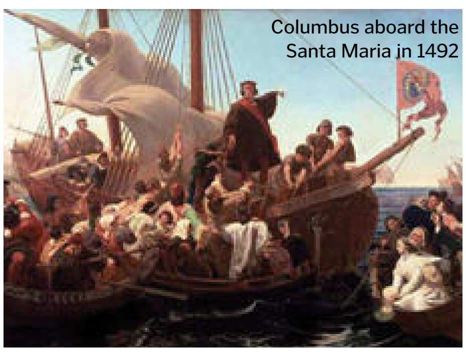
During the first 50 years of its existence, the Fogong Pagoda survived seven earthquakes. The reason for the building's resilience is both its design and building material. The key to its wooden construction is found in its slanting pillars, which act as both external and internal buttresses, and the 54 kinds of bracket arms used to create it. These interlocking sets of brackets, called 'dougong' in Chinese (literally 'cap and block'), provide increased support for the weight of the horizontal beams that span the pagoda's pillars by transferring the weight over a larger area. In this way a building consisting of many storeys may be constructed. Most importantly the use of multiple bracket arms allows structures to be elastic, which is how the Sakyamuni Pagoda has repeatedly withstood earthquakes that have flattened many of its neighbours.

"All survived the voyage from Spain to Haiti but the Santa Maria never made the journey back"

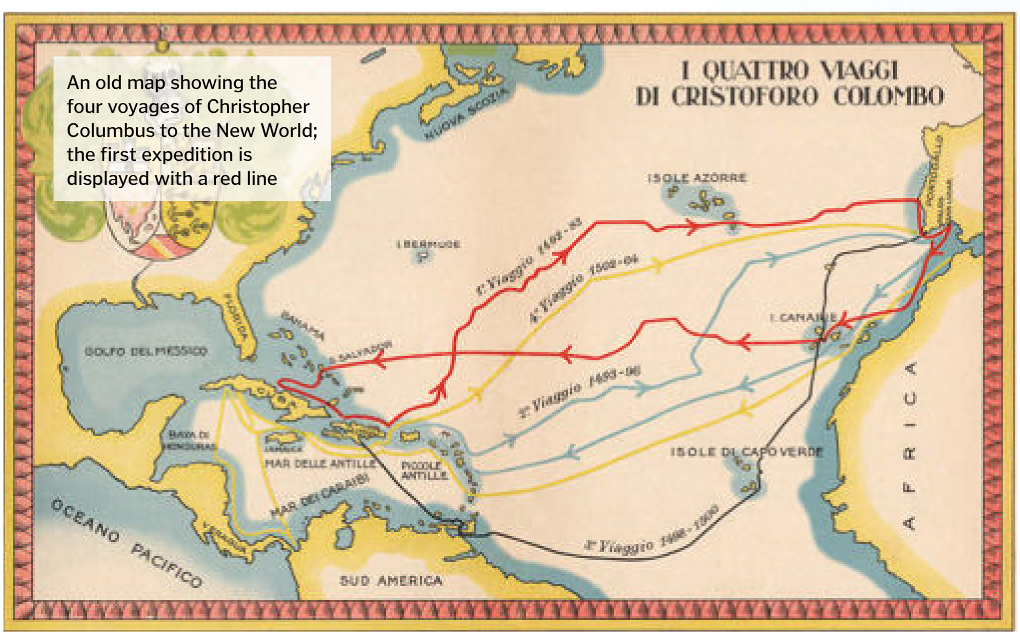
The intrepid voyages of Christopher Columbus

What ships did this explorer command and how did they get him to the New World?

The Niña, Pinta and flagship Santa Maria were the three vessels that made up the small fleet Christopher Columbus took on his first voyage across the Atlantic to the New World. They were relatively small ships: the Santa Maria was a medium-sized carrack (a three or four-masted vessel) around 36 metres (117 feet) long with a burden of 100 or so tons, while both the Niña and the Pinta were caravels (a more lightweight ship) of around half that size. All survived the voyage from Spain to what is modern-day Haiti but, despite being the largest of the trio, the Santa Maria never made the journey back. The ships were secondhand at best and, though carracks were built for extended sailing, the fleet was never designed for such intrepid exploration.


Columbus aboard the Santa Maria in 1492

Santa Maria and its two sister ships left on 3 August 1492 and headed south of the Canary Islands. The idea was to take advantage of the north-east trade winds off Africa, then use the westerlies that prevail across the Azores on the way back. It was an inspirational piece of navigational prowess that paid off, even if it took many weeks longer than anticipated to reach what Columbus thought was the other side of the world and the country of Cipango (Japan) on 28 October; it was in fact Cuba. After a night of celebration, the Santa Maria ran aground near what's now the city of Cap-Haïtien on Haiti. It was damaged beyond repair and Columbus ordered it to be stripped then used to build the new settlement of Villa de la Navidad, while the Niña and Pinta began the voyage home to Spain.



An old map showing the four voyages of Christopher Columbus to the New World; the first expedition is displayed with a red line

New World treasures

The first voyage of Christopher Columbus was funded partly by the Spanish crown and Sevillian bankers, with only a fraction of the total investment that went into the second expedition. It's estimated that he would have needed a minimum of 1.14 million maravedís – the medieval Iberian currency – to secure ships, supplies and fund crew salaries. Needless to say, that was a huge sum of money, although not as much as Columbus would have liked for an expedition of his lofty ambitions.

He returned to Spain minus the flagship of his small fleet and many of his original crew on 15 March 1493, long overdue and having stopped in Portugal due to a storm, which also raised suspicions over his loyalty. However, the parrots, captured natives plus cargo brimming with plundered gold and spices were more than enough to convince the crown that not only was he not a traitor, but a much bigger second expedition was needed as soon as possible.

KEY DATES
COLUMBUS ON TOUR

1492
On 3 August he leaves Palos de la Frontera in Spain with three ships on his first expedition.

1493
He returns to Spain on 15 March the next year with 'souvenirs' for his sovereign investors.

1493
In September, he embarks on a much more ambitious expedition to colonise the New World.

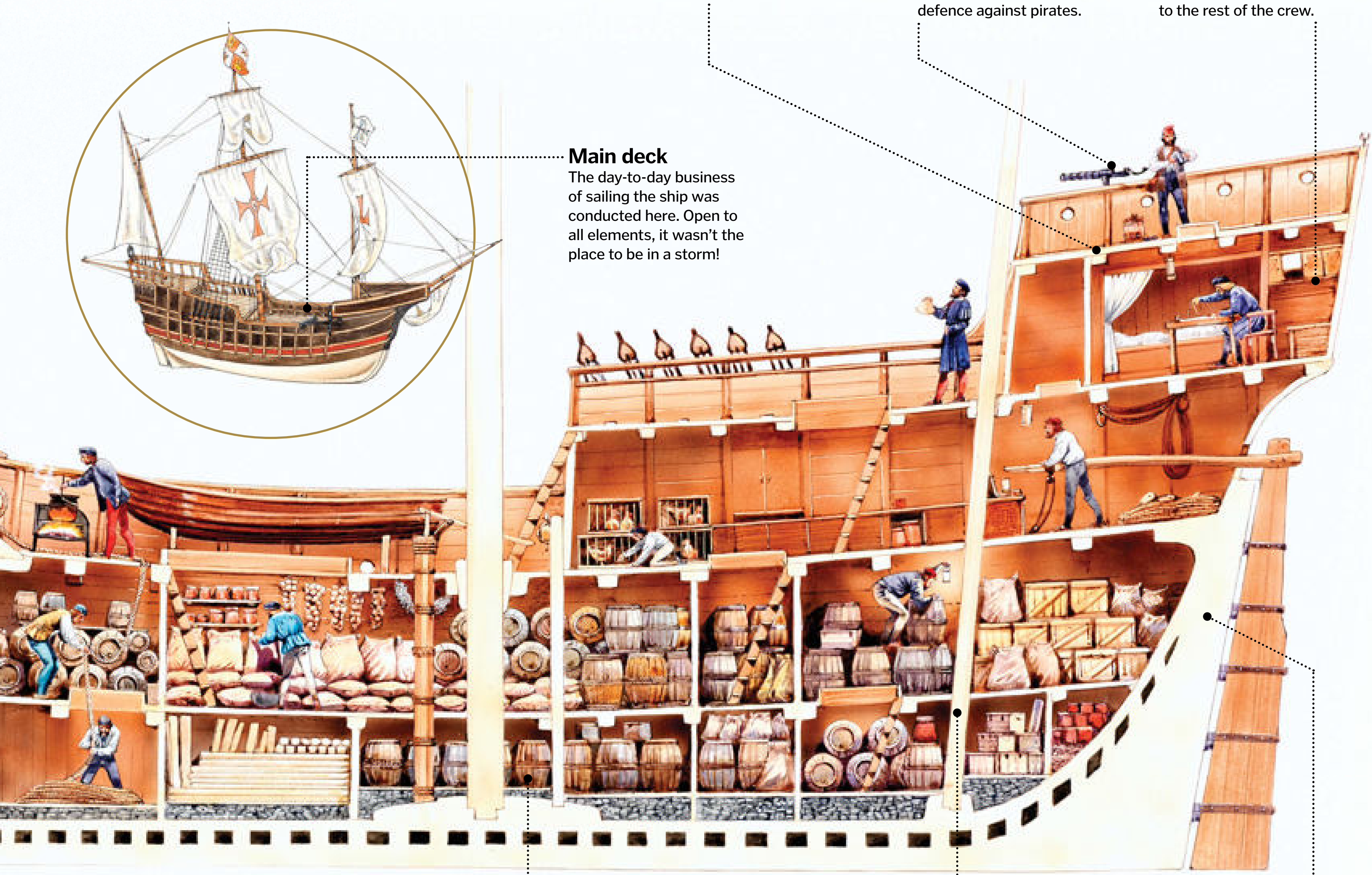
1498
Columbus's third trip was split between a supply mission and further exploration.

1502
Accused of tyranny, Columbus was stripped of his West Indies governorship (right).

DID YOU KNOW? *A fully functioning 1:1 scale replica of the Santa Maria was built for £750,000 ($1.2m) in the Nineties*

The Santa Maria in depth

The structure and contents of Christopher Columbus's flagship from his first expedition



Aftcastle
This section contained Columbus's study, as well as his cabin.

Weapons
Included in the 100-ton burden were several small cannons, used for defence against pirates.

Quarters
The captain and his officers slept in separate, more comfortable quarters to the rest of the crew.

Main deck
The day-to-day business of sailing the ship was conducted here. Open to all elements, it wasn't the place to be in a storm!

Hold
Carracks were designed to carry lots of cargo, so much of the expedition's supplies were stored here.

Bulkhead
Designed to prevent cargo from shifting, the bulkhead actually referred to the wall rather than the room.

Stern
The Santa Maria was a carrack, a type of ship characterised by a highly rounded stern and three or four masts.

Columbus's crew

The crew of the entire fleet consisted mostly of experienced seamen from Andalucía, a southern region of Spain, as well as from Galicia in the north. A few of the crew members were convicted criminals too; they were offered amnesty by the crown if they signed up to what, at the time, was considered a perilous voyage.

The Santa Maria's roll-call is very well known. As the flagship of the fleet, Christopher Columbus was its captain, Spanish navigator and cartographer Juan de la Cosa was its owner and Diego de Arana was the master-at-arms. De Arana was left behind at the new settlement of La Navidad as governor, where Haitian natives later killed him. Academics, craftsmen, a physician and even a painter also made up the roster. Finally, Pedro de Terreros – one of the cabin boys – was left steering the Santa Maria while the rest of the crew celebrated on the fateful night it ran onto a reef off Haiti.

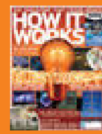
ON THE MAP

Key destinations on the first expedition

1. Spain
2. The Azores
3. Canary Islands
4. Cuba
5. Haiti
6. Japan (where Columbus was originally heading for)

BRAIN DUMP

Because enquiring minds want to know...



Ask your questions

Send us your queries using one of the methods opposite and we'll get them answered

MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in Zoology from Oxford University and another in Real-time Computing. He's been writing about science and tech since before the web. His science-fiction novel *A Jar Of Wasps* is published by Anarchy Books.

Giles Sparrow

Giles studied Astronomy at UCL and Science Communication at Imperial College, before embarking on a career in publishing. His latest book, published by Quercus, is *The Universe: In 100 Key Discoveries*.

Alexandra Cheung

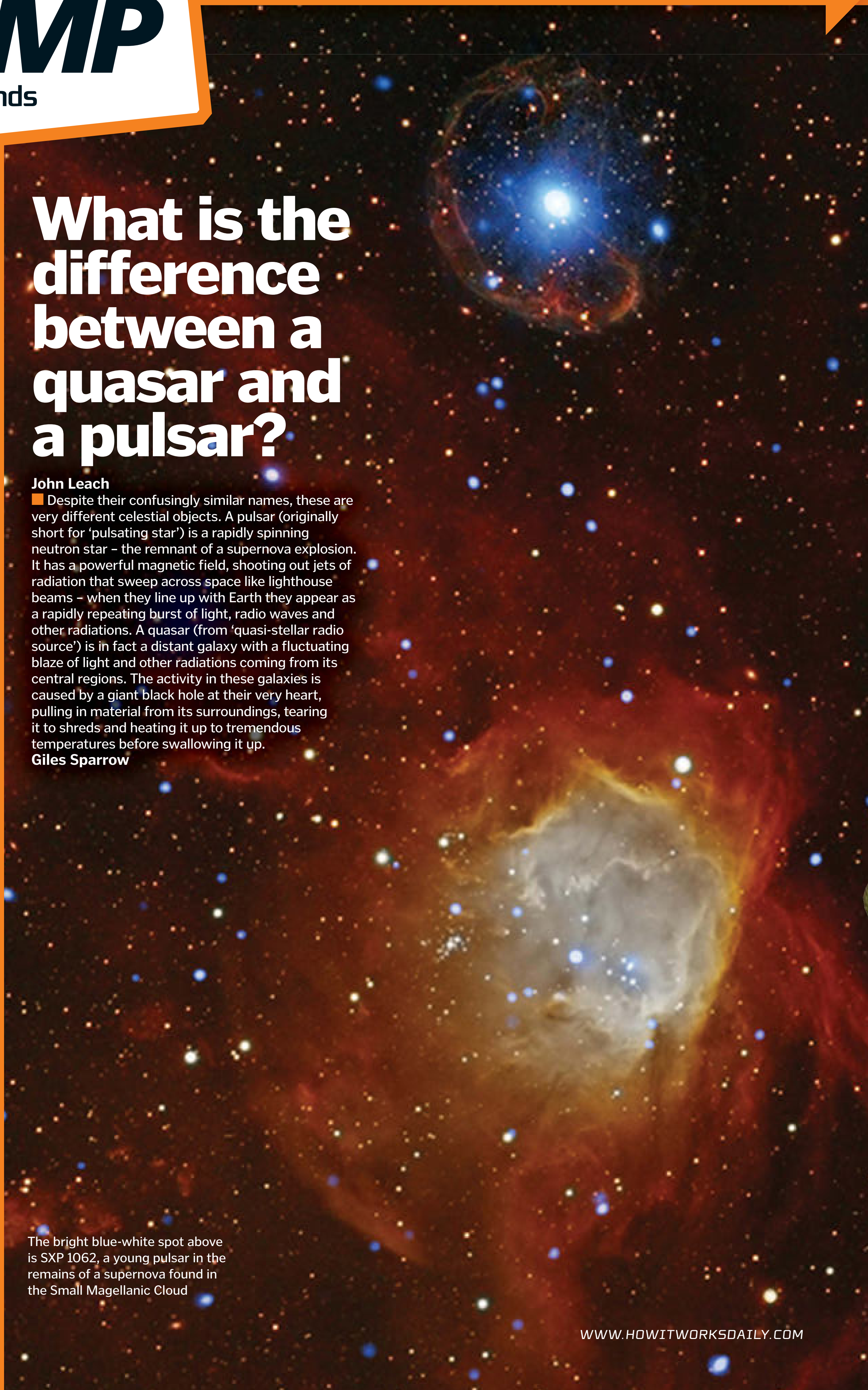
With degrees from the University of Nottingham and Imperial College, Alex has worked for several scientific organisations including London's Science Museum, CERN and the Institute of Physics. She lives in Ho Chi Minh City, Vietnam.

Tom Harris

Hailing from North Carolina, Tom is an experienced science writer who, over the years, has produced hundreds of articles which demystify complex subjects for both magazines and general knowledge books. In his spare time he's a keen dog rescue volunteer.

Dave Roos

A freelance writer based in the USA, Dave has researched and written about every conceivable topic, from the history of baseball to the expansion of the universe. Among his many qualities are an insatiable curiosity and a passion for science.



What is the difference between a quasar and a pulsar?

John Leach

Despite their confusingly similar names, these are very different celestial objects. A pulsar (originally short for 'pulsating star') is a rapidly spinning neutron star – the remnant of a supernova explosion. It has a powerful magnetic field, shooting out jets of radiation that sweep across space like lighthouse beams – when they line up with Earth they appear as a rapidly repeating burst of light, radio waves and other radiations. A quasar (from 'quasi-stellar radio source') is in fact a distant galaxy with a fluctuating blaze of light and other radiations coming from its central regions. The activity in these galaxies is caused by a giant black hole at their very heart, pulling in material from its surroundings, tearing it to shreds and heating it up to tremendous temperatures before swallowing it up. **Giles Sparrow**

The bright blue-white spot above is SXP 1062, a young pulsar in the remains of a supernova found in the Small Magellanic Cloud

Why is blood red?

Joe Murphey

■ Blood is red because it contains iron, bound up in a ring-like chemical structure called porphyrin within haemoglobin – the protein responsible for carrying oxygen around the body. Haemoglobin is crammed into our red blood cells, making them red too. Red blood cells, white blood cells and platelets are the key components of blood, floating in clear plasma, but the sheer volume of red blood cells gives blood a red colour overall. Oxygen-rich blood is a bright red, whereas deoxygenated blood is a darker brownish red. The veins in your wrists may appear blue but they are red too – the blue colour is the result of the way light travels through your skin. While all vertebrates share the same colour blood, blue blood does exist – eg horseshoe crabs have no haemoglobin, having opted instead for haemocyanin, a copper-based protein.
Alexandra Cheung

Is it true that polar bears are actually black?

Tom

■ No, they are definitely white. It is true that polar bear skin is black, but as we all know it's covered by a thick coat of white fur, so the bear as a whole is white.

The colour of a thing is how it appears to your eyes. Think of it like this: if you paint your bedroom walls white, are they 'really' still brick coloured? Taken individually, polar bear hairs are actually transparent. The coat appears white for the same reason clouds do: all the tiny reflections from the myriad jumbled surfaces combine to reflect the light back to your eyes. It used to be thought that each hair acted as an optical fibre to funnel sunlight down to the skin, but recent studies have ruled this out and the white colour is purely for camouflage.
Luis Villazon

Could we resurrect a dinosaur from preserved DNA?

Tim Swindle

■ Bringing back extinct species is a real possibility. In fact, scientists have announced a plan to clone woolly mammoths using remains preserved in the Siberian permafrost. They hope to create mammoth embryos by replacing the nuclei of elephant egg cells with preserved mammoth nuclei, then implanting those embryos in elephants.

The outlook for dinosaur cloning isn't so good however. New research says DNA has a half-life of only 521 years, and that it would break down completely within 6.8 million years. Dinosaurs died out over 65 million years ago, meaning their DNA is long gone.

A possible alternative is to assemble the genetic code of a dinosaur-like animal with a computer, using ancient, 'switched off' dinosaur genes that still exist in the DNA of possible dinosaur descendants, such as birds.

We don't have the necessary technology today, but scientists haven't ruled out this possibility.
Tom Harris

When was Edinburgh Castle built and who lived there?

Peter Stanson

■ Castle Rock, a 130-metre (430-foot) outcrop created by an extinct volcano that was active around 350 million years ago, has been inhabited since the late-Bronze Age, around 800 BCE. The Greek-Egyptian geographer Ptolemy is thought to have recorded a settlement here around 150 CE, but the first reference to a fortification here, known as Din Eidyn, or the Stronghold of Eidyn, comes from a Welsh epic poem circa 600 CE. Archaeological evidence backs up the idea of habitation but shows no signs of a real castle, per se. The first definitive reference of a castle comes from the reign of King David I, who held assemblies of nobles and clerics here from 1139 onwards.
Giles Sparrow

Why don't ancient mummies decompose? Find out on page 84

BRAIN DUMP

Because enquiring minds want to know…

Which is the tiniest nation?

Find out on page 85

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered

Why are some genes stronger than others?

Lindsey Adams

■ 'Strong' genes are called dominant and require just one copy of themselves to have an effect. Recessive genes need two copies to exert their influence (ie you need to have inherited a copy from both your parents). Dark eyes are a dominant trait as it only takes one copy of the relevant gene to stimulate the eye to produce melanin – the pigment that colours eyes brown. Blue eyes, on the other hand, are recessive as the presence of melanin masks the blue colour – somebody with one gene for blue eyes and one for brown eyes will have brown eyes. This is just one of the many ways in which dominant and recessive genes interact, but there's still a lot more for scientists to learn about how they work.
Alexandra Cheung

Is cave-aged cheese actually matured in caves?

Sean Marshall

■ For centuries, cheesemakers have been ageing their product in subterranean caves. The reason is that cheese ripens best at a steady, constant low temperature (10-13 degrees Celsius/50-55 degrees Fahrenheit) and high humidity (88-92 per cent). If there aren't any caves available, cheesemakers use stone cellars or temperature-controlled rooms for the same purpose. The ripening process is what gives each cheese its particular texture, colour, fragrance and taste. Industrial cheesemaking relies on refrigeration and additives that speed up the process. Artisan cheesemakers may age hard cheeses like cheddar for two years!
Dave Roos

Which animal has the best eyesight?

James Daniels

■ Birds of prey boast the greatest visual acuity of all animals and zoologists believe some hawks and eagles have vision eight times sharper than ours. An eagle's retina sports approximately 1 million sensory cells per square millimetre – around five times what you'd find in a human retina. It pays off: some birds of prey can spot and track a rabbit 1.5 kilometres (0.9 miles) away!

If you gauge eyesight in terms of light spectrum perception instead of acuity, the mantis shrimp is the champ. Mantis shrimp perceive 11 or 12 primary colours, putting our three to shame, and they see ultraviolet and infrared light too. But their greatest trick is the ability to perceive both linear polarisation and circular polarisation of light, a talent no other animal possesses.
Tom Harris

Why don't mummies rot?

Jenna Townsend

■ The miracle of mummification is how a body buried nearly 5,000 years ago could remain intact, while a non-mummified body decomposes into a pile of dust in just a few hundred years. The key is desiccation – removing all moisture from the body and storing it in an extremely dry environment. Bodies rot because bacteria thrive in the moist conditions of decaying flesh and organs. Bacteria can't live, however, where there is no water. In Ancient Egypt and South America, the first mummy-making cultures probably found animals whose skin remained intact after dying in extremely dry places – both hot and cold. To replicate this process, Egyptians removed all of the deceased's internal organs and coated the body inside and out with a salt mixture. After 40 days or more, the salt would have drawn all of the moisture from the body. Organs were dried separately and either placed in urns or back inside the body. Mummies were also stuffed with sawdust before being treated with naturally antibacterial oils and wrapped in layer upon layer of sticky resin and linen. Mummification didn't always work, but if the body was fully dried, carefully wrapped and stored in a perfectly dry place, the skin and bones would remain preserved for millennia.
Dave Roos

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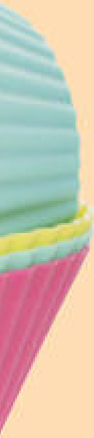


How is silicone made?

Natalie P

Silicone starts out as silicon dioxide (SiO_2), or silica, found in abundance in rocks and sand. Transforming it into silicone requires replacing the two oxygen atoms bound to the silicon atom with organic, carbon-based groups.

Firstly, silica is heated inside a furnace, driving oxygen out and leaving elemental silicon – the same stuff that is used in computer chips. The silicon is powdered, then combined with a copper catalyst and methyl chloride, forming several different silanes. These are separated out and hydrolised to produce siloxanes – chemicals with a backbone of alternating silicon and oxygen atoms which are the basic building blocks for many types of silicone. Silanes and siloxanes can be combined with each other or other additives to make silicone fluids, gels and resins with a variety of useful properties.

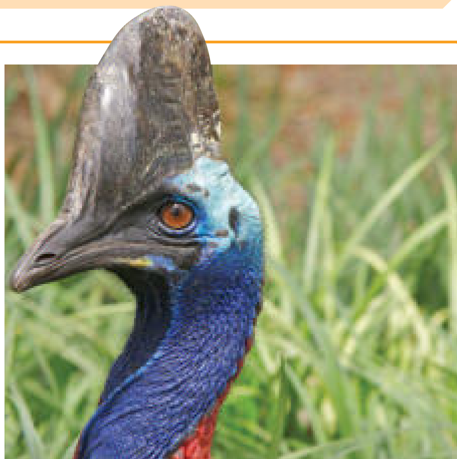
Alexandra Cheung

How high do you have to go to see the curvature of Earth?

Gregory Peet

According to optical researchers, while we can fool ourselves into thinking we see the curvature of the Earth from high mountains, this is usually wishful thinking. You should be able to detect it from an aeroplane at a cruising height of around 10,600 metres (35,000 feet), but you need a fairly wide field of view (ie 60 degrees) and a virtually cloud-free horizon. The reality is that clouds, hills and mountains mean we rarely get to see the kind of perfectly flat horizon where the curve would be most obvious. However, you can detect the curve of the Earth from ground level at the coast with a pair of binoculars – just look for distant ships on the horizon and you'll see that their hulls start to disappear before their masts and other superstructure. Ancient Greek scientists, who spotted this without any optical aids, used this to conclude that the Earth was round.

Giles Sparrow



What is the cassowary's crown for?

Francesca

Cassowaries are large flightless birds, only slightly smaller than an ostrich or emu, that live in the forests of New Guinea and north-east Australia. Their most distinctive characteristic is the large crest, or crown, on the top of their head. The outside is hard like a horn, but the inner part has a honeycomb-like structure to keep the weight down.

There are lots of theories for the purpose of the crown. It may have originally evolved to protect the bird's head. Cassowaries eat fallen fruit and the wedge-shaped crest would help deflect any fruit/seeds tumbling from the treetops. Cassowaries can also run at 48 kilometres (30 miles) per hour, and as they career through the forest they lower their heads to push through the undergrowth. But the honeycomb interior does more than just save weight – it also acts as an amplifier. Cassowaries have the deepest call of any bird. The note is so low it is only just audible to humans, but the crown acts as a resonating chamber that allows this sound to carry through the dense forest. Besides these useful qualities, the cassowary's crown may play a decorative role as well. Like the peacock's tail, size matters when it comes to attracting a mate.

Luis Villazon

What is this odd bug I found?

Helen Turner

It's an elephant hawk-moth (Deilephila elpenor) caterpillar. The caterpillars hatch in July and pupate at the end of the summer to overwinter. Then the adults emerge around May the following year. The caterpillars live mainly on willowherb and they get their name because the front has a thin snout that looks a bit like an elephant's trunk. When it is threatened, the caterpillar pulls this 'trunk' into the front body segment, which makes it swell up. Combined with the eye spots on the head, this makes it look like a snake and deters birds.

Luis Villazon

Which is the smallest country in the world?

George McKenny

At 0.44 square kilometres (0.17 square miles), Vatican City is the planet's smallest country. A procession of popes owned and ruled portions of Italy for over 1,000 years until the mid-1800s, when the Kingdom of Italy seized most of the papal land. The 1929 Lateran Treaty established the independent state of Vatican City, the pope's residence and spiritual centre of the Roman Catholic Church. Around 800 people live in Vatican City and only 570 people hold Vatican City citizenship. The only 'military' force is the Pontifical Swiss Guard, a corps of single Catholic bodyguards recruited from the Swiss Army.

Dave Roos

Do some wasps eat meat? Find out on page 86

BRAIN DUMP

Because enquiring minds want to know...

What are tufa towers?
Find out on page 87

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered

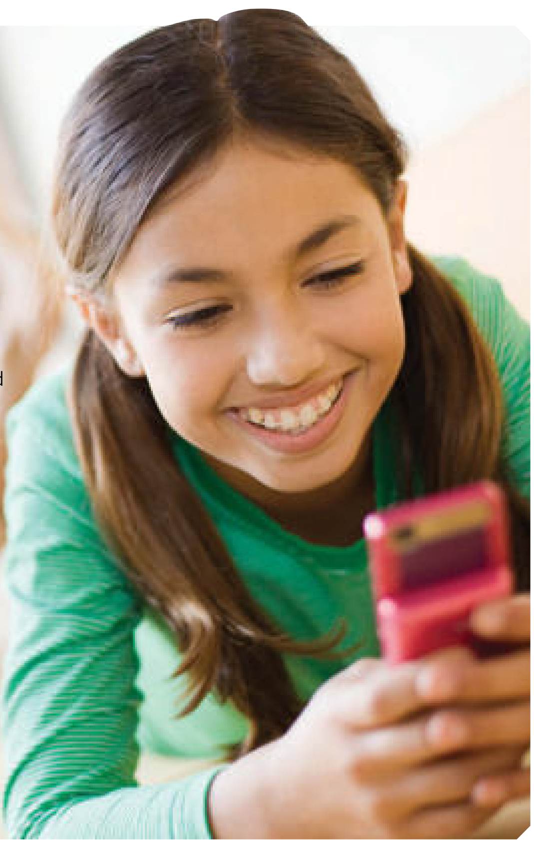
How far can we see into the past through a telescope?

James Anderson

It all depends on the size of the telescope! Our ability to treat the universe like a great cosmic time machine is due to the limited speed of light – even though it's the fastest thing in the cosmos it can still only travel at 9.5 trillion kilometres (5.9 trillion miles) per year, so all the light from distant objects that we are seeing now set out on its journey at some time in the past.

Even with the naked eye, you should be able to spot the Andromeda galaxy, one of our closest galactic neighbours, which is equivalent to looking about 2.5 million years back in time. A small telescope will reveal galaxies tens of millions of light years away – light from some of the galaxies in the Virgo Cluster set out on its way to Earth around the time the dinosaurs became extinct. The most distant galaxy so far seen with the Hubble Space Telescope, announced in November 2012 and known as MACS0647-JD, is 13.3 billion light years away, so we are seeing back to a time just 420 million years after the Big Bang. And radio telescopes can do even better than that, detecting weak microwaves from the afterglow of the Big Bang itself, some 13.7 billion years ago.

Giles Sparrow



Why are text messages limited in characters?

Dale Clark

In the mid-1980s, a group of telecommunications researchers in Europe were trying to devise a standard way to send text messages through a brand-new technology called the mobile phone. Their best hope was to use a secondary radio channel on mobile networks reserved to transmit bits of data about reception strength. But the narrow data channel would only allow a limited number of characters. The chairman of the research group, Friedhelm Hillebrand, conducted a non-scientific study of postcards, Telex transmissions and his own list of frequently asked questions to determine that 160 characters would be enough for most communications. As a result, the short message system (SMS) was born. So if you ever run out of characters, blame Mr Hillebrand.

Dave Roos

A yellowjacket wasp bites off a chunk of carrion before flying it back to its nest to feed the larvae

Are there carnivorous wasps?

Randal

Not in the sense of eating a diet of solely meat. Almost all wasps are parasitic as larvae, with the eggs laid into the paralysed body of an insect host so the larvae can eat it when they hatch. The adults generally just feed on nectar, much as bees do. The parasitic wasp species are all solitary, but there are a few species of social wasp, with sterile workers providing for a reproductive queen. Some of these, such as yellowjackets, are omnivorous and both adults and larvae will feed on dead insects, fallen fruit and even carrion. The wasps that make a nuisance of themselves at picnics are normally the social species. The adults have sharp mandibles that can slice through flesh and carry it back to the hive, however they are scavengers and won't normally tackle living prey.

Luis Villazon

How are tufa towers formed?

Michael Chu

Tufa towers are columns of calcium carbonate which form in carbonate-rich saltwater lakes (soda lakes). Underneath the lake, underwater springs pump calcium-rich water through the lake bed. When the spring water meets the alkaline lake water, calcium and carbonate salts react to form insoluble calcium carbonate (limestone), which precipitates out, settling in mineral deposits around the spring. Over centuries these deposits gradually grow into towering columns which can reach heights of up to nine metres (30 feet). Tufa can only form underwater, so it is only if lakes are drained or dry out over many years that the towers are exposed.
Alexandra Cheung

Estimated to have formed 1-3 million years ago Mono Lake is one of the oldest lakes in North America

Is fur the same as hair or are they completely different?

Matt Haines

Hair and fur are two words for the exact same thing: thin fibres made from the protein keratin. These fibres grow out of organs called follicles, which you'll find in the skin of nearly all mammals, from mice to elephants. The only difference between hair and fur is the kind of mammal you're talking about. Fur is reserved for non-human animals, while hair can mean fibres on either animals or humans.

Of course, a human head of hair and an animal's fur coat do have some key differences. A typical furry animal, like a cat, sports a dense coat of very fine individual fibres. Human heads have a less dense coat of thicker individual hairs. Additionally, the hair on our heads grows to greater lengths thanks to a unique activity cycle. The hair on your arms or legs, akin to animal fur, is in the growth stage (called anagen) for 19-26 weeks before reaching an intermediate phase (catagen) followed by a shedding phase (telogen). In contrast, the hair on your head might be in the anagen phase for two to six years. The follicles and fibres themselves are the same, but our genes make them follow different cycles.
Tom Harris

Are storks dinosaurs and why do they have such long legs?

Mary Crofton

The prevailing opinion among palaeontologists is that birds are direct descendants of theropod dinosaurs from the Jurassic period. The counter-view is that birds are actually descended from other prehistoric reptiles. If the dinosaur lineage theory is correct, then storks – and indeed all birds – could be classified as a dinosaur subgroup. But this is a bit like saying whales are ungulates (hoofed land animals), as they are ungulate descendants. Storks likely evolved long legs as a means of walking through tall grass and shallow water, searching for fish, frogs and other prey. Palaeontologists believe a flying dinosaur ancestor – the giraffe-sized pterosaur – may have hunted the same way.
Tom Harris

THE KNOWLEDGE

FOR CONNOISSEURS OF KIT AND SAVANTS OF STUFF

Razer DeathStalker Ultimate keyboard

Price: £229.99/$249.99
Get it from: www.razerzone.com
'DeathStalker Ultimate' is hardly a title you'd associate with a keyboard, but when you're marketing to the hardcore gamer, you can't mince about with the name. It has to be as brash and as over-specced as the product itself – and the Razer DeathStalker Ultimate is bursting at the seams with features for PC gamers. Glowing keys and ultra-low profile aside, it comes with macro support, allowing multiple functions to be programmed onto one key or combination of keys, on the fly. Anti-ghosting allows for up to ten simultaneous key presses and, like all Razer products, it comes with the Razer Synapse software suite. The main event is the 10.3-centimetre (four-inch) touchscreen and trackpad for gesture support, dubbed the Switchblade UI, which gives an extra level of control. It's pricey, but serious gamers won't be disappointed.

Plantronics Marque 2 M165

Price: £49.99/$59.99
Get it from: www.plantronics.com
Whether you're driving, jogging, commuting or forging your way through the urban jungle, sometimes it's just not practical to be fumbling around in your pocket for your mobile. This is where a Bluetooth headset proves useful: the Plantronics Marque 2 is completely hands-free. Simply say 'Answer' or 'Ignore' to manage calls, or stream music and directions when within a range of up to ten metres (33 feet). It's also capable of eliminating noise in busy or windy areas and boasts up to seven hours' talk time.

HOW IT WORKS

What is polling?

In the computing world, polling is the number of times the status of a peripheral is sampled by the CPU. Modern peripherals often have their own chips to process this information for the computer.

HOW IT WORKS

Dual-mic noise reduction

The Marque 2 improves noise reduction by employing two microphones and verifying on input against each other.

ThumbsUp! Touch Speaker

Price: £29.99/$N/A
Get it from: www.thumbsupworld.co.uk
From the word go this speaker certainly got a big thumbs up from us. It's not as if your jaw would graze the floor if we told you it's a kind of speaker dock for smartphones – we're inundated with smartphone speaker solutions, after all. But this employs a brand-new piece of technology that is about to shake the market by the lapels. If you take a smartphone – an iPhone, Galaxy S III or anything – place it on top of the Touch Speaker and play some music, the audio will instantly be boosted. No wires or Bluetooth handshaking are required, the device just 'hears' the tinny speaker sound and gives it a bit of welly with a respectable amount of bass. This is because it uses near-field audio (NFA), a technology that can boost electronic audio when in close proximity to the source. It's lightweight and powered by USB or three AA batteries, making it one of the most versatile portable speaker systems we've seen yet.

Disco 2 Bluetooth stereo speaker

Price: £79.99/$99
Get it from: www.supertooth.net

You don't want to mess around with wires and fiddly pairing when it comes to syncing a device with a speaker, so the Disco 2 does it very simply: charge up its integrated rechargeable batteries, switch it on and then search for the Disco 2 via your Bluetooth connections on your mobile device. Click to link and your music will stream via the 16-watt RMS, twin-speaker and bass all-in-one system. It offers a respectable level of audio for any decent-sized room at home or work.

Massive: The Higgs Boson And The Greatest Hunt In Science

Price: £9.99/$12.99
Get it from: www.eburypublishing.co.uk

Ian Sample, award-winning science correspondent for *The Guardian* newspaper, has written a book about the pretty-hot topic of the Higgs boson. In our experience, reading anything about this subatomic particle in the last six months, since last July's five-sigma announcement, generally sees us either drowning in quantum physics or wincing through tenuous metaphors. Sample's dodged adeptly around both of these by weaving the history of the Higgs boson right back to Peter Higgs' Sixties paper, and by leaning on his unprecedented access to the reclusive man himself. For such a technical and potentially dry subject, it's actually a fascinating read.

HOW IT WORKS

NiMH cells

Nickel-metal hydride (NiMH) batteries are rechargeable batteries similar to nickel-cadmium (NiCd) cells, but with up to three times the capacity.

HOW IT WORKS

NFA vs NFC

NFC requires a digital 'handshake' between devices, so the gadget needs to be NFC compatible. NFA, on the other hand, is totally agnostic to modern communication standards between various devices.

HOW IT WORKS

The Higgs field

This force is said to bind elementary particles of the universe together, lending them mass. The Higgs boson is the field's signature particle.

APPS OF THE MONTH

Brought to you by **Apps Magazine**, your essential guide to the best iPhone and iPad apps available on the Apple App Store

iPad: The Orchestra

Price: £9.99/$13.99
Developer: Touch Press LLP
Version: 1.0.1
Size: 1.81GB
Rated: 4+

Learn your Beethoven from your Berlioz with this detailed exploration of classical music. The Orchestra offers multiple video and audio tracks of Esa-Pekka Salonen conducting the world-renowned Philharmonia performing extended extracts from eight works. It's a multimedia feast with various camera angles to watch the conductor and co, as well as live scores that carry you through the piece, and even an impressive beat map à la GarageBand. You'll also find audio commentaries from the conductor and interactive images.

Verdict: ★★★★★

iPhone: Reactable Huntemann

Price: £1.49/$1.99
Developer: Reactable Systems SL
Version: 1.0.2
Size: 22.2MB
Rated: 4+

DJ Oliver Huntemann and music creation app franchise Reactable have created a truly interactive experience, producing an album that you can remix yourself. Original samples can be looped, effects added and you can play with a synthesiser, oscillator and sample player.

Verdict: ★★★★☆

Apps magazine

ISSUE 29 ON SALE NOW!

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High-end binoculars

We check out three pairs of binoculars for the more discerning naturalist

Ostara Prophecy 8x42

Price: £249.99/$N/A
Get it from: www.clearviewbinoculars.co.uk

We rarely get to play with a pair of compact binoculars that cost more than £100, so it was hard to imagine what extras we would get with a pair worth £250. Optical Hardware's Ostara Prophecy binoculars cover a range of magnifications and diameters according to taste, so we opted for a typical 8x42: something you'd probably take on a family outing to the local nature reserve. The viewing experience is far from typical though. An especially crisp image housed in a lightweight body with comfy rubber eyecups makes these binoculars nearly as natural as viewing with our own eyes. There's a very slight azure tint to the image from the optical coating, but it's barely noticeable. The Ostara Prophecy series is also watertight, so they can be completely immersed in water and remain undamaged. Interestingly, the body is filled with nitrogen gas, which prevents the lenses from fogging up even in high humidity. Admittedly it's a lot of money, but you do also get a case, flotation strap and a 30-year guarantee included.

Verdict: ★★★★☆

Olivon WP-Pro 7x50

Price: £279.99/$N/A
Get it from: www.opticalhardware.co.uk

If popping a pair of binoculars into a pocket or hanging them easily off your neck doesn't come high on your list of priorities, then perhaps you'd prefer to spend your money on a really tasty pair of traditional binoculars. Due to the refinements that compact optics require to get the image right, they attract a premium. So, being in a similar price bracket to both the FieldTracker and Ostara compact models we've featured here, the Olivon WP-Pro should, overall, provide a superior image at the cost of increased weight and bulk. With a 7x50 magnification/objective lens diameter, the exit pupil (the aperture the user looks into) is very big – great for using around dusk, when bad weather sets in or times when light is generally low. Coupled with a broad field of view and sharp BAK4 prisms, it's a viewing experience that's hard to put down. They are also shock resistant, waterproof, extreme temperature resistant and come with a case and ten-year guarantee – a package that really puts the compact trade-off into perspective.

Verdict: ★★★★★

Visionary FieldTracker EmeralD 8x42

Price: £279.99/$N/A
Get it from: www.clearviewbinoculars.co.uk

If you want to look more like a pro ornithologist, then these are the compacts for you. They feature a green rubber-armoured body that helps protect against knocks and blends in well with the great outdoors. But other than that there's not a lot to separate these from the Ostara Prophecy binoculars. With the same 8x42 magnification and objective diameter, the Visionary FieldTracker EmeralD offers a reasonable field of view and superb clarity. Though getting our eye position just right took a bit of fumbling, we quickly got used to that. They also feature anti-fogging and dioptre adjustment on the right barrel, which is used for those with non-standard vision who need the slightest fine-tuning to equalise the image from both lenses. ED (extra-low dispersion) glass is used to prevent chromatic blurring, although sometimes it does leave the image tinged with yellow. We'd go for the Ostara Prophecy simply for the 20 extra years of warranty.

Verdict: ★★★★☆

HOW TO...

Essential skills for surviving in the modern world delivered step by step

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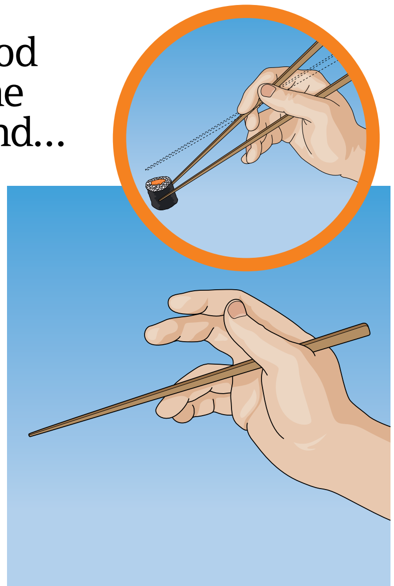
Eat with chopsticks

Tired of dropping food when forks are off the menu? Help is at hand…

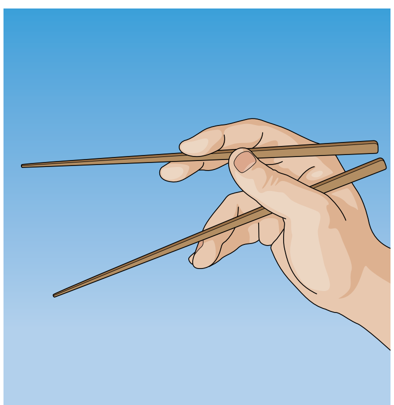
1 Starting position

Firstly, rest one of the chopsticks in the gap between your thumb and index finger. When positioning, ensure the chopstick sits roughly two-thirds up its total length (with the fat end at the top and the narrow end at the bottom). Once this is in place, you can rest the edge of the chopstick against your ring finger (as pictured) to secure it.



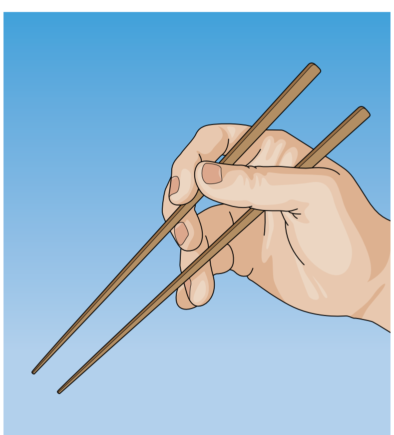
2 Get a grip

Secondly, grip the other chopstick between the tips of the index and middle fingers – again, do so roughly two-thirds up its total length so that the two sticks are roughly parallel. If you have positioned the second stick properly, its fat end should be resting against the upper index finger. Both chopsticks should now be aligned.



3 Pincer action

Now comes the tricky part. Use your index finger to bring the upper stick's tip into contact with the lower, fixed chopstick. This is best achieved by gently squeezing the upper-side of the moving stick with your index and middle fingers. If done right, the two sticks should meet, allowing a pincer action to pick up food. The secret is never to move the lower stick.

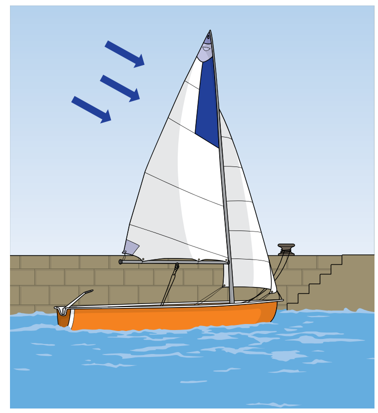


Sail a boat

More landlubber than salty seadog? Read these tips before hitting the water

1 Judge the wind

With the boat fully rigged the first thing you should pay attention to is the wind direction in relation to your boat. This, as you might expect, is crucial to get moving. Sailboats can't sail directly into the wind but can travel up to 45 degrees towards it, so positioning of the hull and the sails is key. Ideally you want to be sailing directly downwind, but this isn't always possible.



2 Reposition

To leave the dock you must first release the mooring line; it seems obvious but it's easily forgotten! Now you need to reposition the boat so the sail can catch the wind – referred to as 'backing the sail'. This is achieved by simply pushing the boom arm out to either side. This will cause the wind to blow against the back of the sail and force the boat to turn from its moored position.

3 Get your balance

As soon as the sails are catching the wind and the boat is moving, position yourself on the opposite side to the boom. This is necessary as the wind, if left unchecked, will cause the boat to heel (lean over). By doing this, your weight should prevent the vessel from capsizing. In smaller sailboats, a seated position is best as it's harder to lose balance.

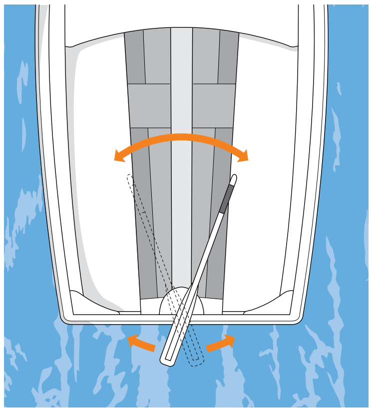
> *"In smaller sailboats, a seated position is best as it's harder to lose balance"*

Disclaimer: Neither Imagine Publishing nor its employees can accept liability for any adverse effects experienced when carrying out these projects. Always take care when handling potentially hazardous equipment or when working with electronics and follow the manufacturer's instructions.

NEXT ISSUE
- Survive a snakebite
- Read a sundial

4 Master steering

Directional steering is – for the most part – achieved through positioning of the tiller. This horizontal bar is attached to the rudder post and, through its manoeuvring, allows the rudder (located underwater) to be turned. Remember that the directional motion of the tiller is reversed on the rudder. In other words, to turn left you need to move the tiller right and vice versa.



5 Acceleration

To speed up and slow down both the mainsheet and jib sheet need to be adjusted, so they move closer to the centre line of the boat. Firstly pull the mainsheet until the mainsail stops flapping and then do the same for the jib sheet. If this is done right you should feel the boat speed up. As a general rule, the closer you are sailing to the wind, the more the sails should be pulled in.

6 Coming to a stop

It's all well and good zooming off but you need to be able to stop too. This is done by 'spilling wind'. To do this let out the sheets until the sails begin to flap slightly, at which point the wind will have little effect. To stop completely, turn the boat directly into the wind and loosen the sheets. This will cause the boat to come to a halt within a couple of lengths where it can be re-moored.

In summary...

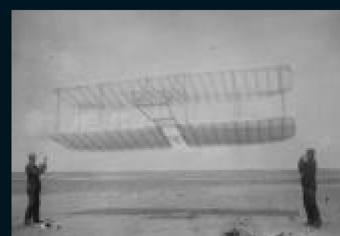
Operating a small sailboat, while not an easy task, is simple enough if you remember a few key principles. Firstly, controlling the sail sheets is vital to both acceleration and deceleration, with flapping, loose sheets unable to efficiently pick up the wind. Secondly, maintaining an even weight distribution is crucial to remaining stable – the operator should position themselves on the opposite side to the boom and mainsail. Lastly, sailboats can't ever move directly into the wind, with progress only possible up to roughly a 45-degree angle towards it.

TEST YOUR KNOWLEDGE

ENJOYED THIS ISSUE? WELL, WHY NOT TEST YOUR WELL-FED MIND WITH THIS QUICK QUIZ BASED ON THIS MONTH'S CONTENT?

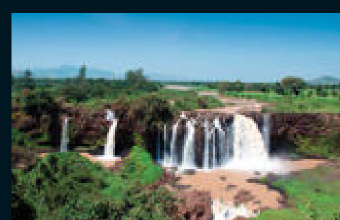
1 The operation to remove our tonsils is known as what?

2 After which scientist is the Doppler effect named?



3 What did the Wright brothers repair as kids?

4 How many floors does the Pearl River Tower have?



5 At which city do the White Nile and Blue Nile converge?

6 Cassowaries can run at up to what speed (km/h)?

7 What type of ship was Christopher Columbus's Santa Maria?

8 In which year did Chinese Emperor Daozong erect the Sakyamuni Pagoda?

9 What is Jupiter's escape velocity in km/h?

10 Castle Rock in Scotland has been occupied since which era?

ENTER ONLINE

at **www.howitworksdaily.com** and one lucky reader will win a starter set model of Nelson's famous flagship HMS Victory. Good luck!

ISSUE 43 ANSWERS

1. 7,310mph **2.** Renault Fuego Turbo **3.** 2.31sec **4.** Holocene **5.** -268.9°C **6.** 16 **7.** Aleksei Leonov **8.** 15.7cm **9.** Last **10.** 150MYA

INBOX

Feed your mind. Speak your mind

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Although made famous by the 1980 eruption Mount St Helens' volcanic history has been dated back at least 300,000 years

Win! A WOWee One portable speaker

Get in touch!

We enjoy reading your letters every month. So keep us entertained by sending in your questions and views on what you like or don't like about the mag.

FANTASTIC PRIZE FOR LETTER OF THE MONTH!

WOWee ONE™

WIN A WOWEE ONE PORTABLE SPEAKER

This issue's top letter wins a WOWee One Classic portable speaker. This turns any surface into a bass amplifier using gel technology, and is compatible with all iDevices and other mobile gadgets.

Letter of the Month

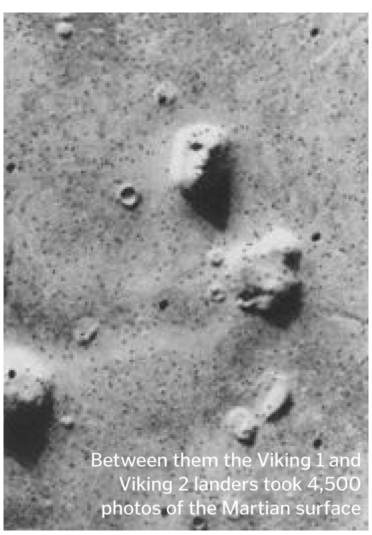
A lesson in volcanology

Hi HIW,

I was reading **How It Works** issue 42 when I came across the article about Mount St Helens in Washington State [page 60-61]. At the top of page 61 it says about an eruption 3,600 years ago that was considerably more powerful than the one that occurred in 1980, when Native Americans had to flee. After reading this, I started to wonder how we even know a mega-eruption like this happened so long ago. If you could provide some evidence then I would be interested to find out more.

Harry Wheeler

Although there have been a number of large eruptions from the many volcanoes in Washington, USA, one of the biggest did occur at Mount St Helens around 3,600 years ago. Volcanologists use radiocarbon dating and a technique that estimates the age of eruptions based on the deposits of ash they leave – a bit like reading the age of a tree by cutting a section out of its trunk and looking at the rings. This event was still tiny compared to some of the giant eruptions in the nearby Yellowstone region, which were thousands of times more energetic than both the 1980 and ~1,600 BCE eruptions. Enjoy your prize!



Between them the Viking 1 and Viking 2 landers took 4,500 photos of the Martian surface

Facing up to the facts

Dear How It Works,

I have a question: why when you draw a random squiggle and draw an eye into it does it look like a character?

Bence (12)

This is a psychological phenomenon known as pareidolia, when arbitrary sensory stimuli appear significant in some way. It's most commonly a visual thing, sight being our dominant sense and, more often than not, people will see faces in clouds or hear voices and music in white noise. A prime example is a famous photo taken by Viking 1 as it approached Mars, which appears to show a face in the planet's surface (left).

Nuclear inspiration

Hello HIW,

I was enlightened by your article on nuclear fission and fusion in issue 42. All my life I thought nuclear power produced radioactive waste and was ultimately against the idea (mainly due to how long the waste took to decay). However, your article has opened my eyes and spurred me on to learn more.

Thank you!

Darryl Hough

Bedtime reading

Hey,

Thanks for a wonderful magazine. I've been on the lookout for a while now for an intelligent magazine for my 11-year-old son to enjoy that wouldn't bore him either. We were still discussing and reading some of the great articles well past his bedtime tonight and we had a great time doing so!

Jane-Maree English

Silk power

Hi HIW team,

I really enjoy your magazine. I had a question after reading about the space elevator which was mentioned in issue 31 (page 21). Knowing that 'experts theorise that a pencil-thick strand of spider silk could stop a Boeing 747 in flight', couldn't we just make a space elevator cable out of alternating layers of spider silk and cryogenically hardened steel (which was also discussed in the same issue but on page 36)?

Trevor Wells (14)

Although finer than a human hair spider silk is super-strong and super-stretchy and, as a result, super-interesting to scientists

"We don't know how to replicate spider silk synthetically yet and silk farming is very impractical"

The toughest known spider silk is made by the Darwin's bark spider; it is many times stronger than steel and more elastic than Kevlar. This is a great idea in theory, Trevor, but unfortunately we still don't know how to replicate spider silk synthetically yet and spider silk farming is very impractical. Weirdly though, genetic engineering has produced goats that create spider silk protein in their milk – we couldn't make that one up!

Tooth-waste

Dear HIW,
In your answer to the Brain dump question 'What is toothpaste made of?' [which appeared in issue 40], I was disappointed to see that the content made no reference to the aluminium extraction article in the same issue. For it is the very same sodium fluoride waste product from the aluminium process that is also used in Prozac (fluoxetine) and various other psychiatric drugs and anaesthetics and is also used in toothpaste and water fluoridation. This is why toothpaste manufacturers include a warning on their labels as it contains up to 1,500 parts per million (ppm).

I think it is very important that readers fully understand that although fluoride does indeed start its life as a natural product in the ground, the so-called sodium fluoride used in toothpaste is the unnatural and toxic end waste product of the aluminium extraction process described in the article on page 29.
Thanks for a great magazine.
Steve Clarke

What's happening on...
Twitter?

We love to hear from **How It Works**' dedicated readers and followers, with all of your queries and comments about the magazine and the world of science, plus any topics which you would like to see explained in future issues. Here we select a few of the tweets that caught our eye over the last month.

@londonguidechap
@HowItWorksmag
Having hot choc at @LTMuseum

@spritneybeers
@HowItWorksmag
Brilliant! I got a new iPhone a couple of weeks ago and this is just what I needed! Thank you

@gilma57
@HowItWorksmag
With the number of new customers I'm getting to join, my school should get a free subscription!

@JeremyLuxemburg
@HowItWorksmag
Depends how you define 'nation'! There are 1,000 islands [sic; there are nearer 7,000 islands] in the Caribbean, about 30 nations, 13 of which are independent

@benekkee
@HowItWorksmag
According to Brian Cox we're all just made up of tiny proton gradients. I feel really special now :(

@jaybobbybob
@HowItWorksmag
I love the way NASA calls the 200-million-light-year-away void near us the 'Local Void', like it's next to the newsagent down the road!

HOW IT WORKS

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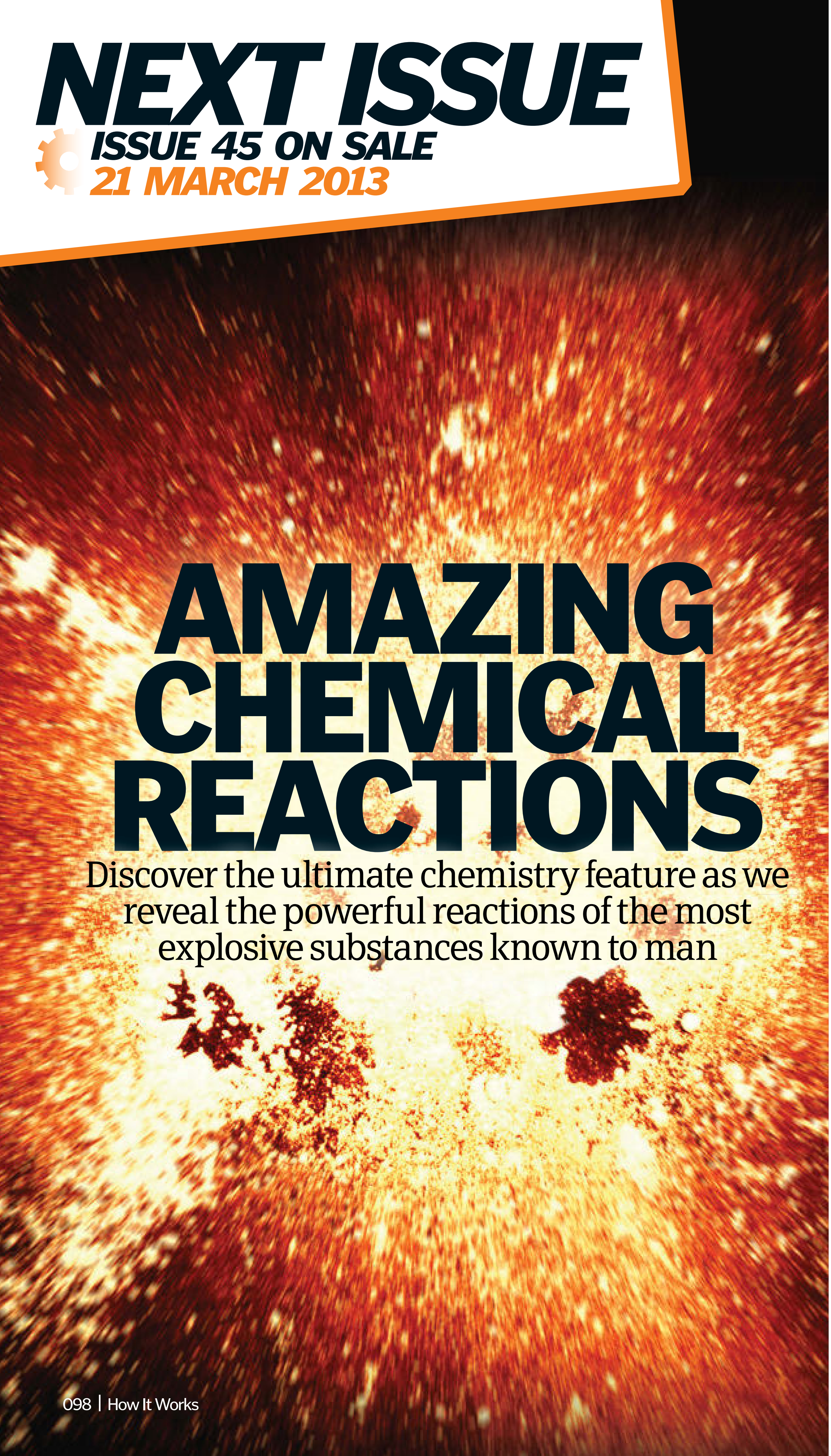

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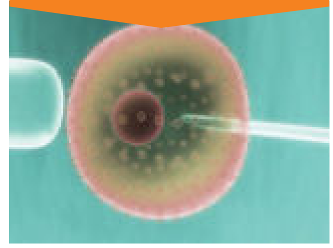
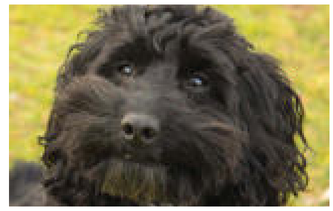
Discover the ultimate chemistry feature as we reveal the powerful reactions of the most explosive substances known to man

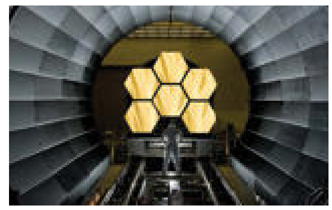
ANSWERED NEXT ISSUE



What are human stem cells capable of?

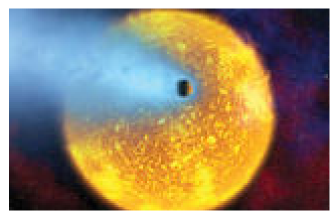


Why is a dog's sense of smell so acute?



How far can the biggest space telescopes see?

How do bomb-disposal robots disarm mines?



Is the planet Osiris really evaporating?

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